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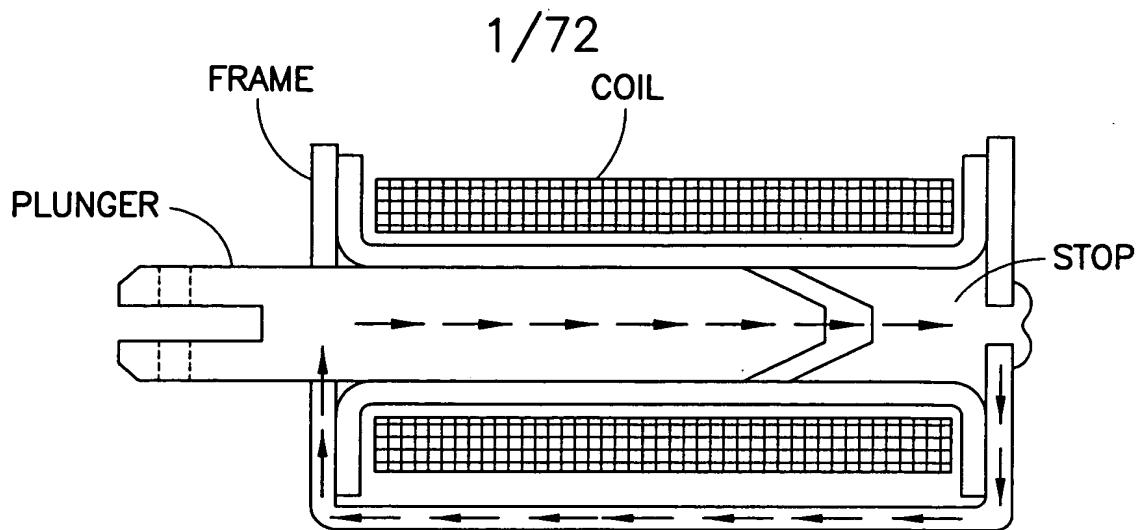
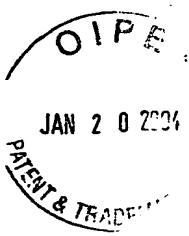


FIG. 1A

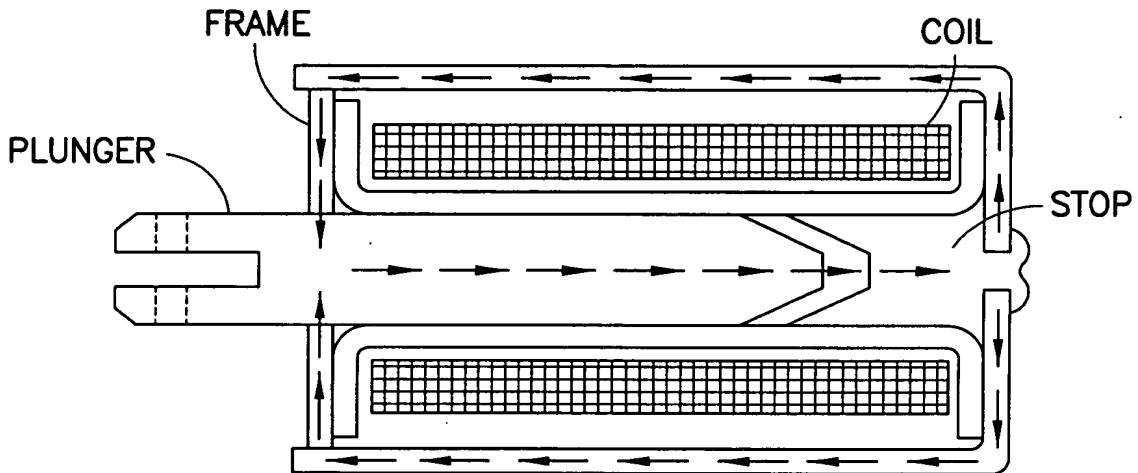


FIG. 1B

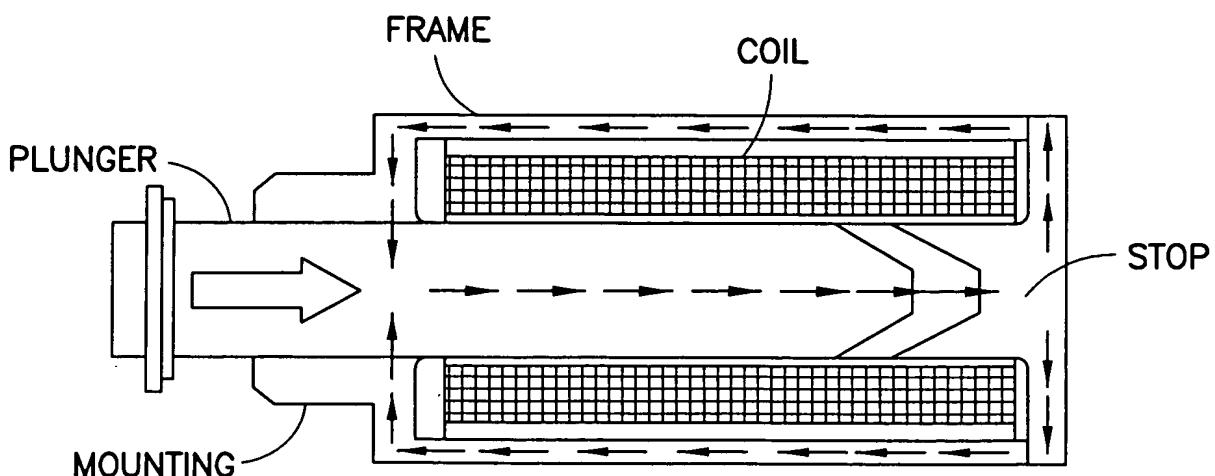


FIG. 1C

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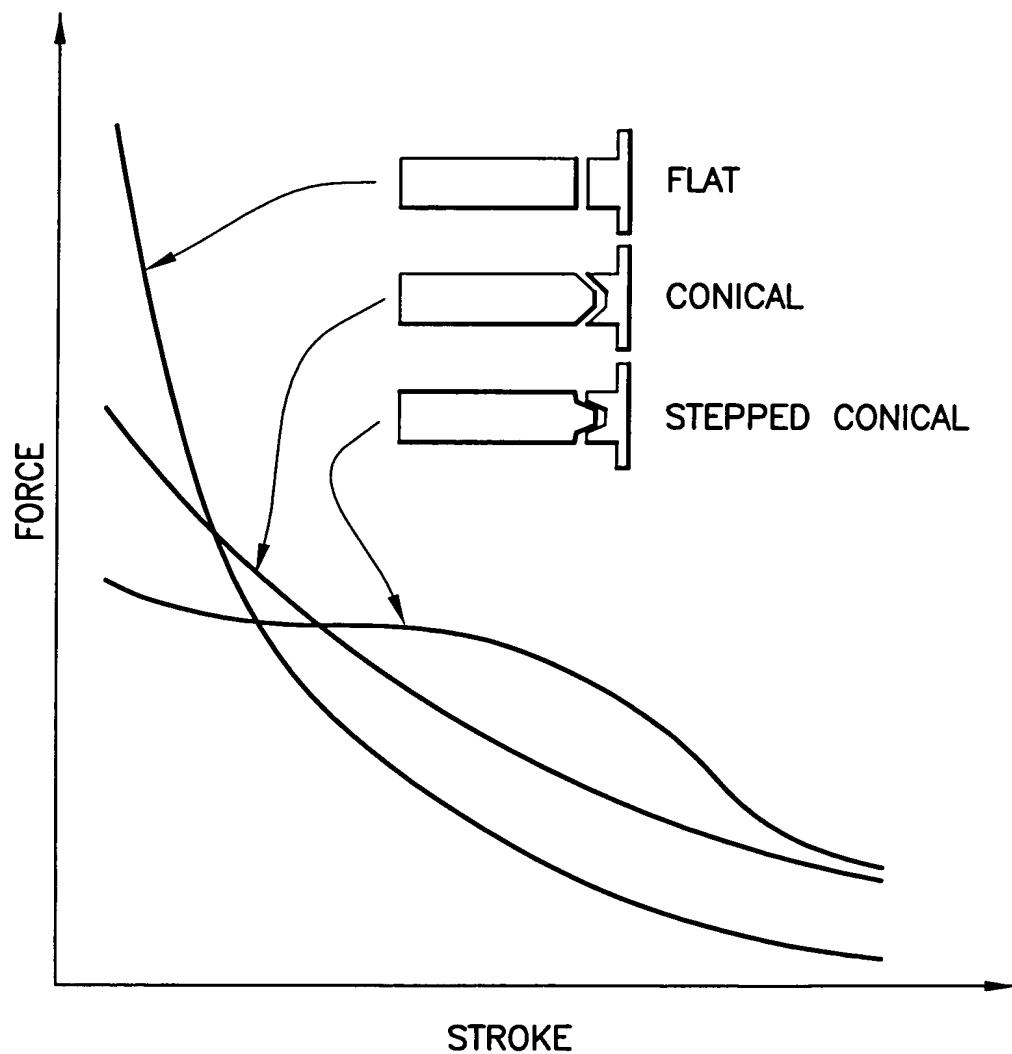
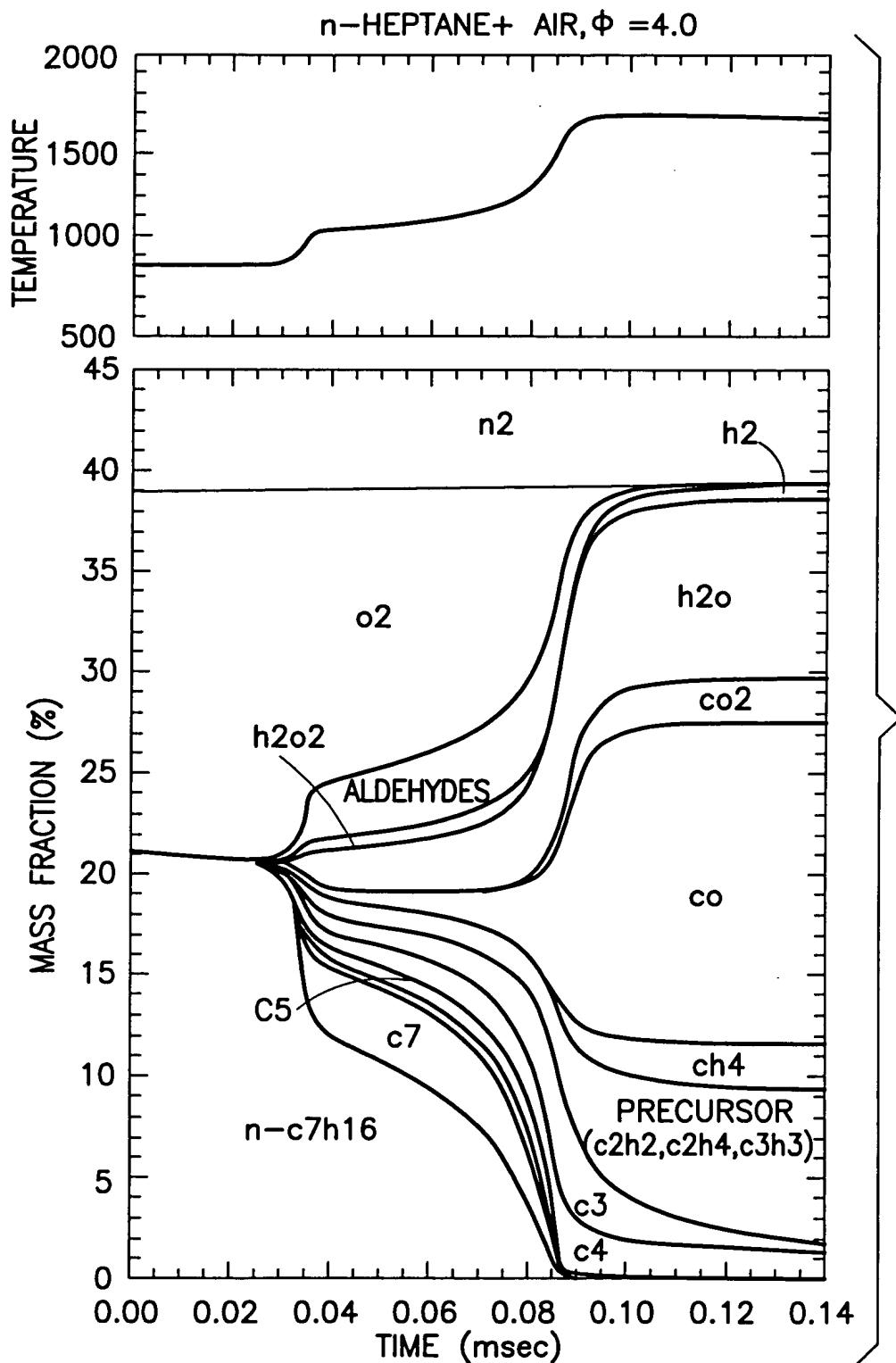


FIG.2

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NORMAL HEPTANE REACTIONS STARTING
AT 900 °K AND 83 BAR

FIG.3

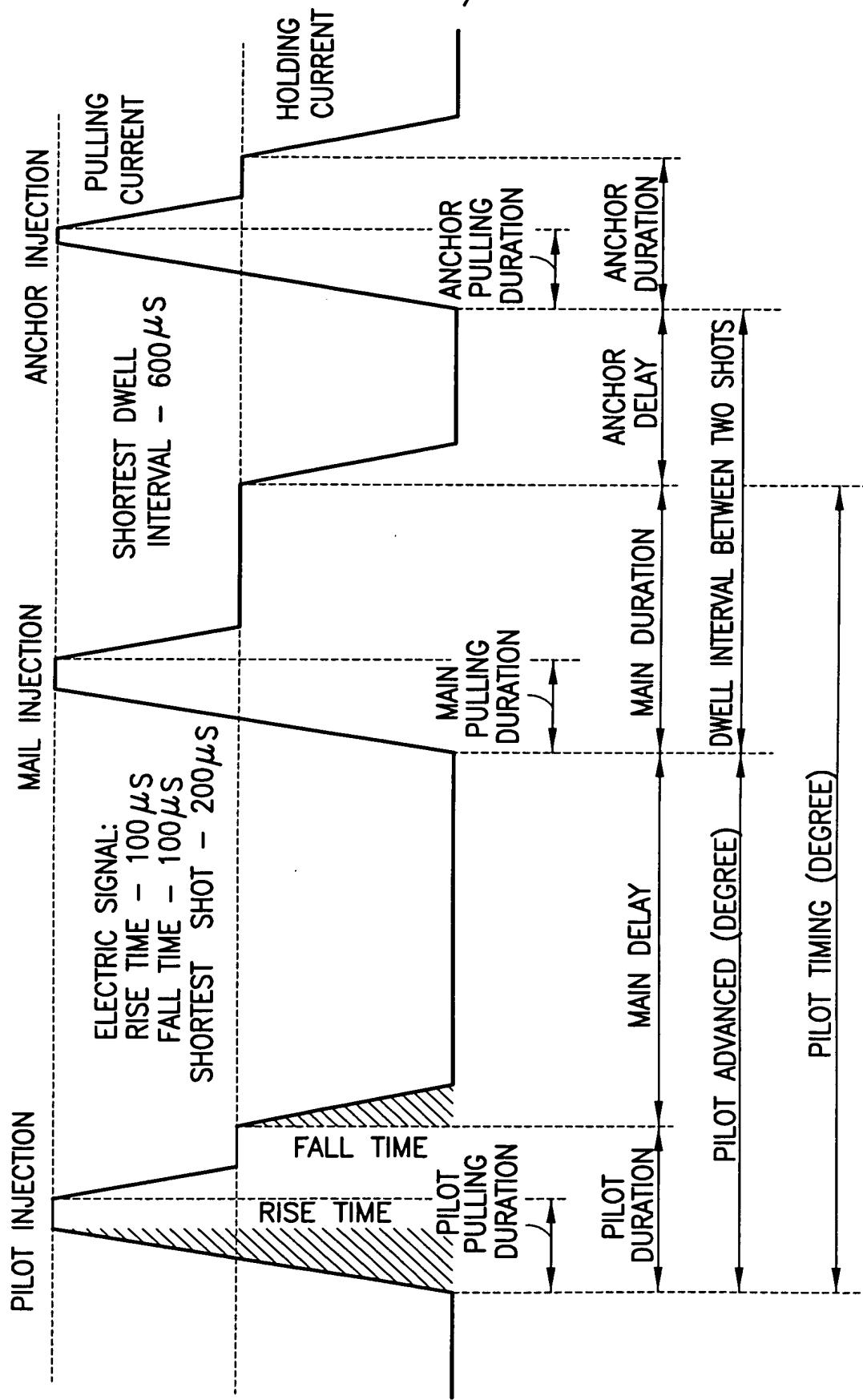
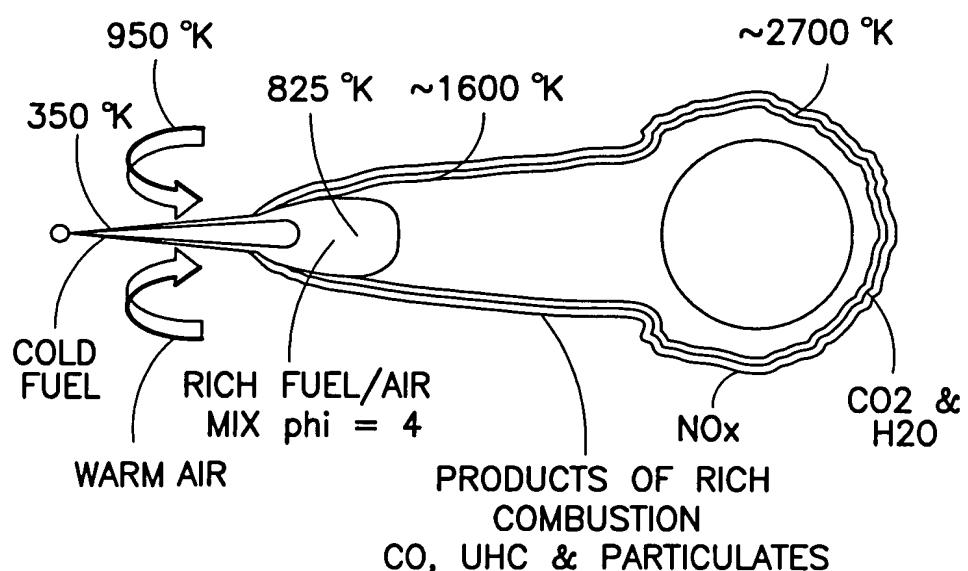


FIG.4

TEMPERATURES



CHEMISTRY
SUMMARY OF FUEL BURNING PROCESSES

FIG.5

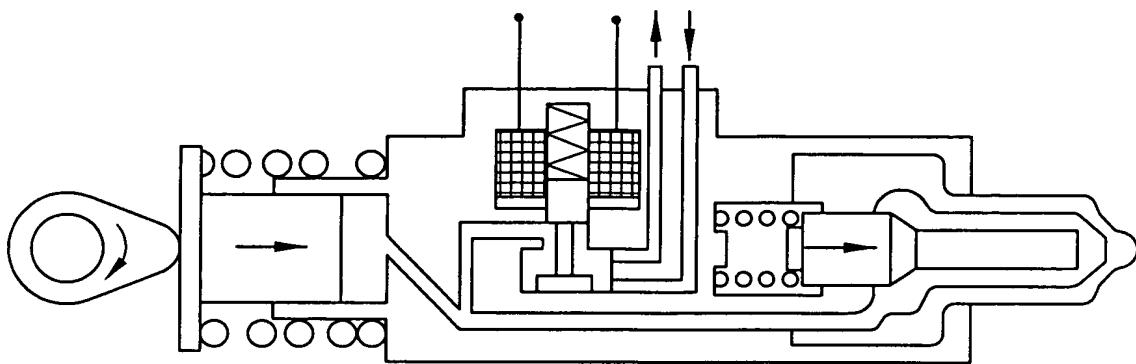


FIG. 6D

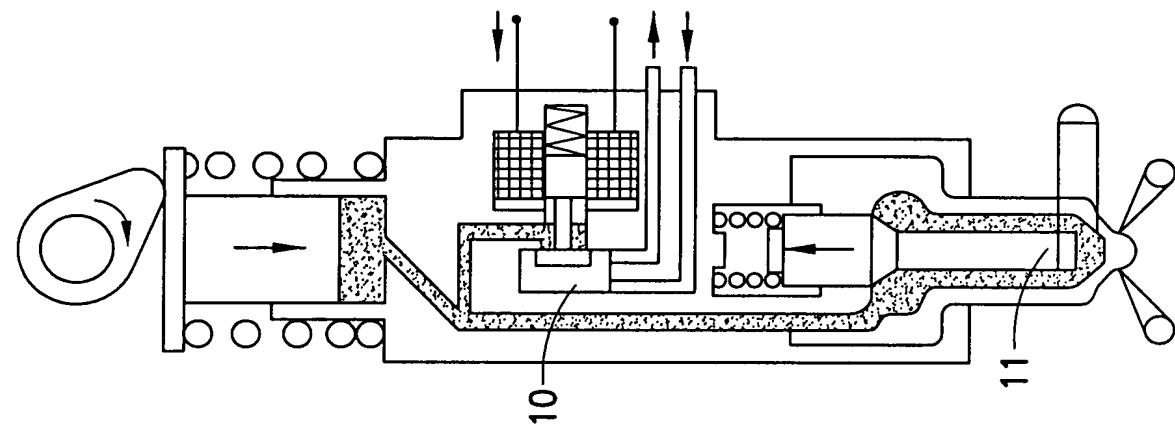


FIG. 6C

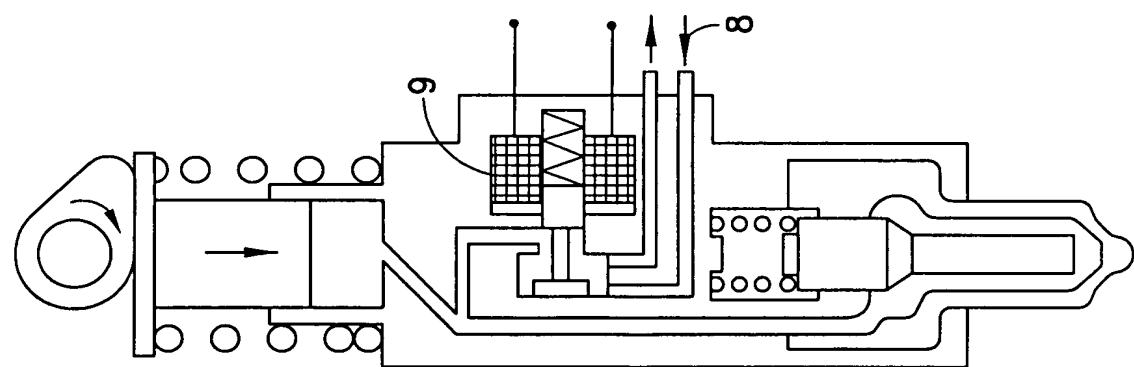


FIG. 6B

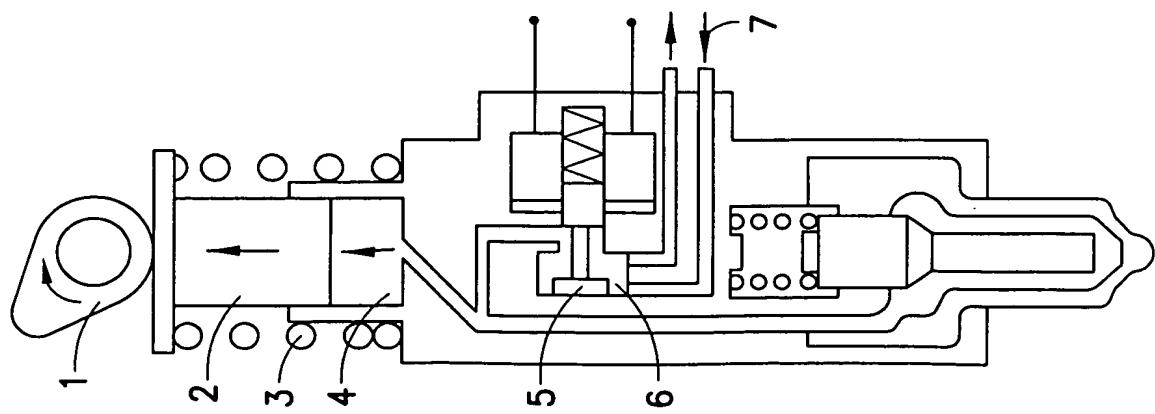


FIG. 6A

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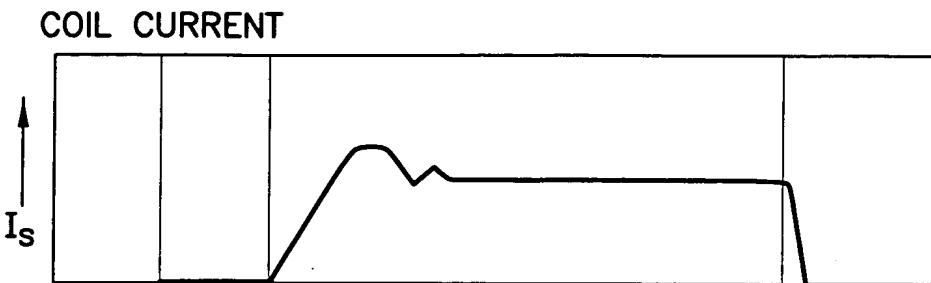


FIG.7A

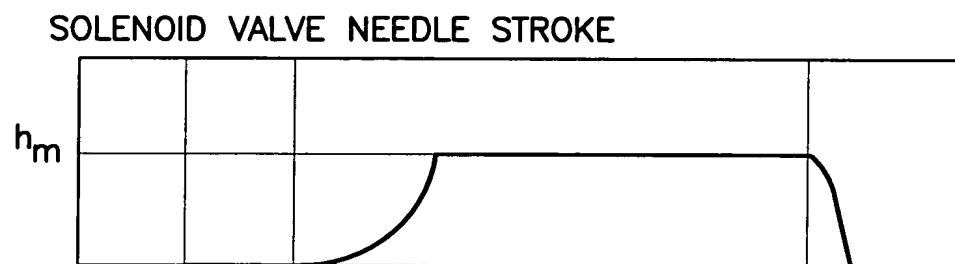


FIG.7B

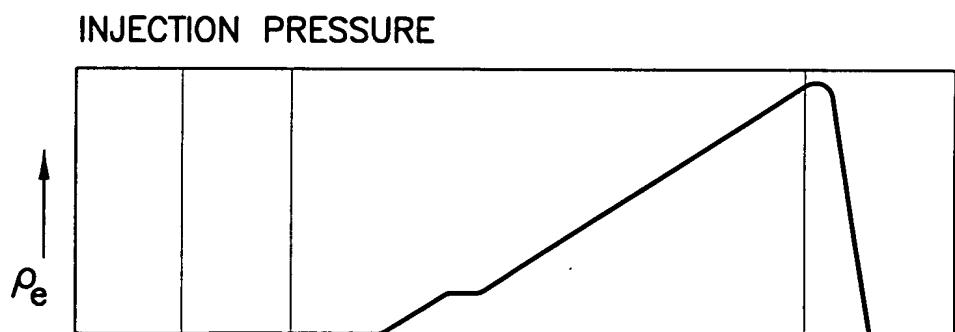


FIG.7C

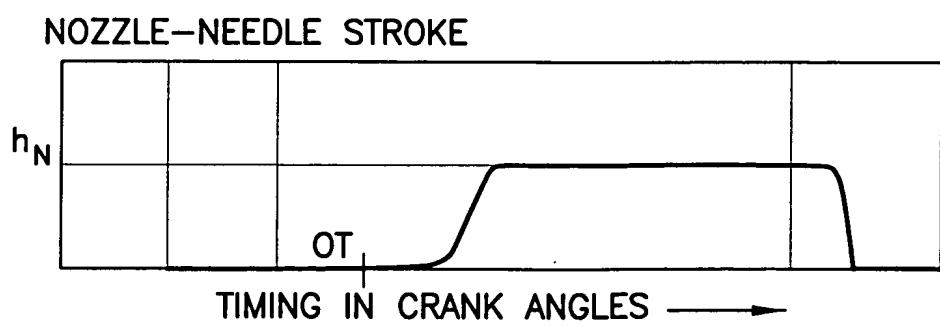


FIG.7D

WAVE FORM DIAGRAM: OPERATION OF THE FUEL INJECTION NOZZLE

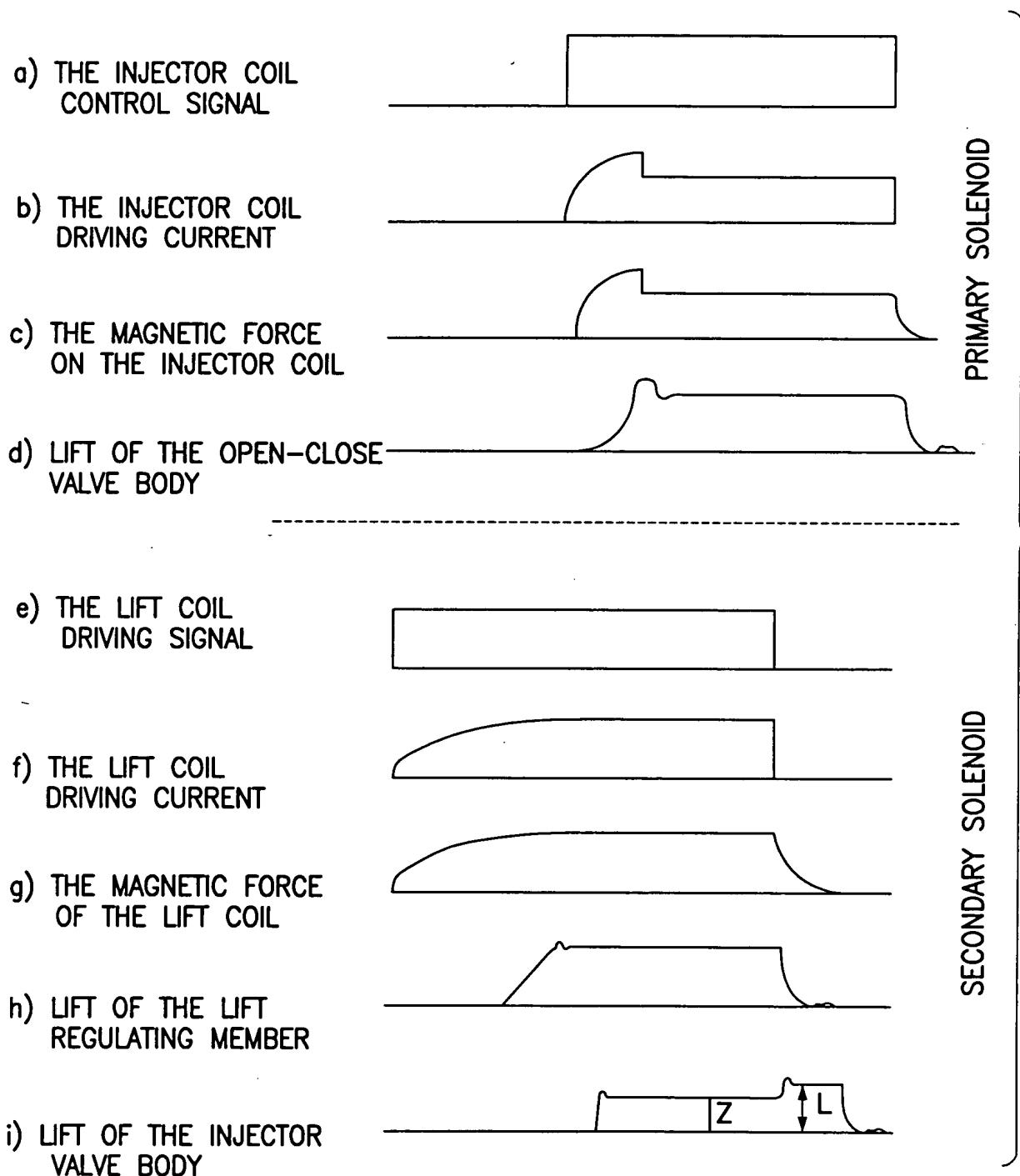


FIG.8

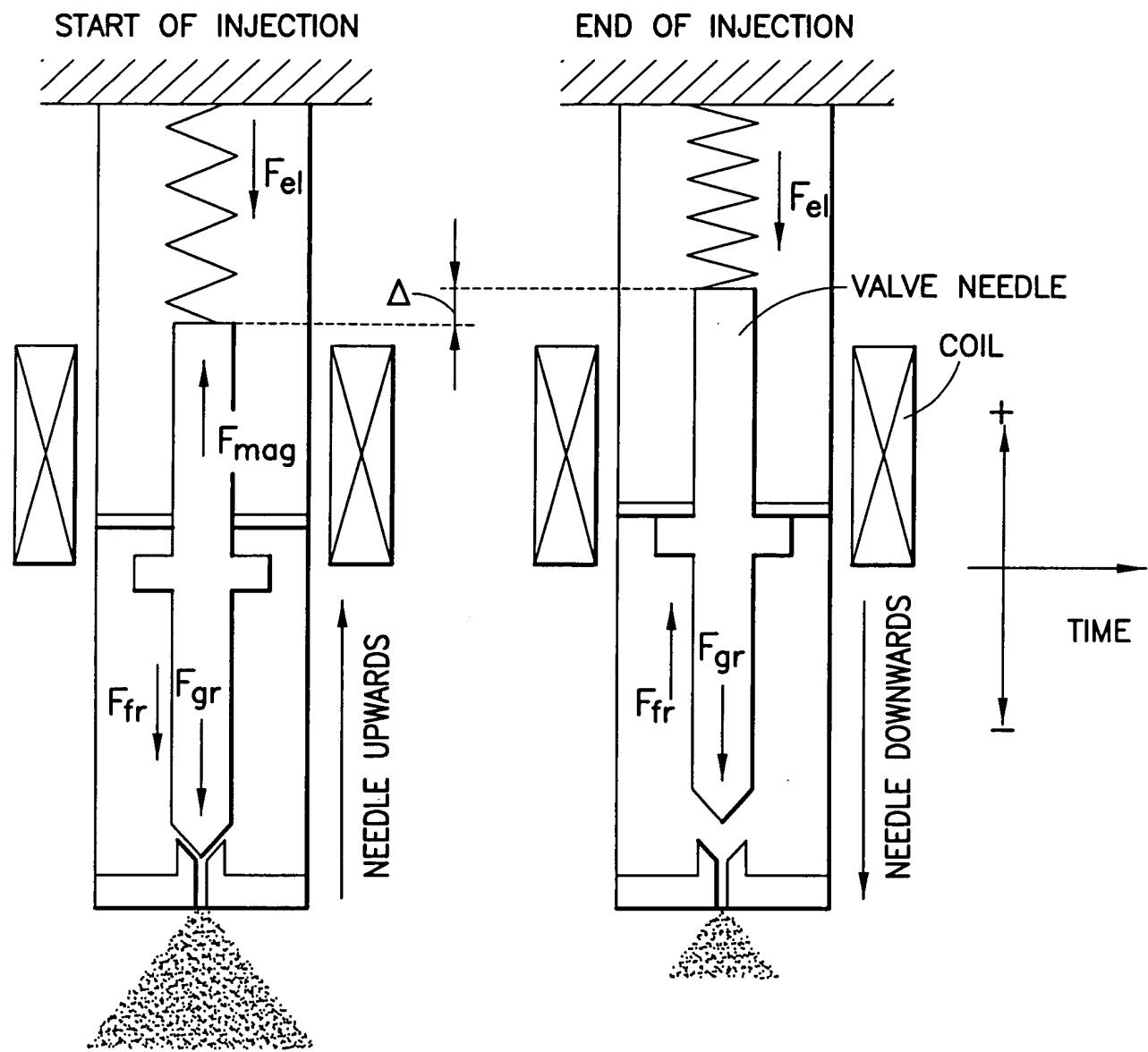


FIG.9

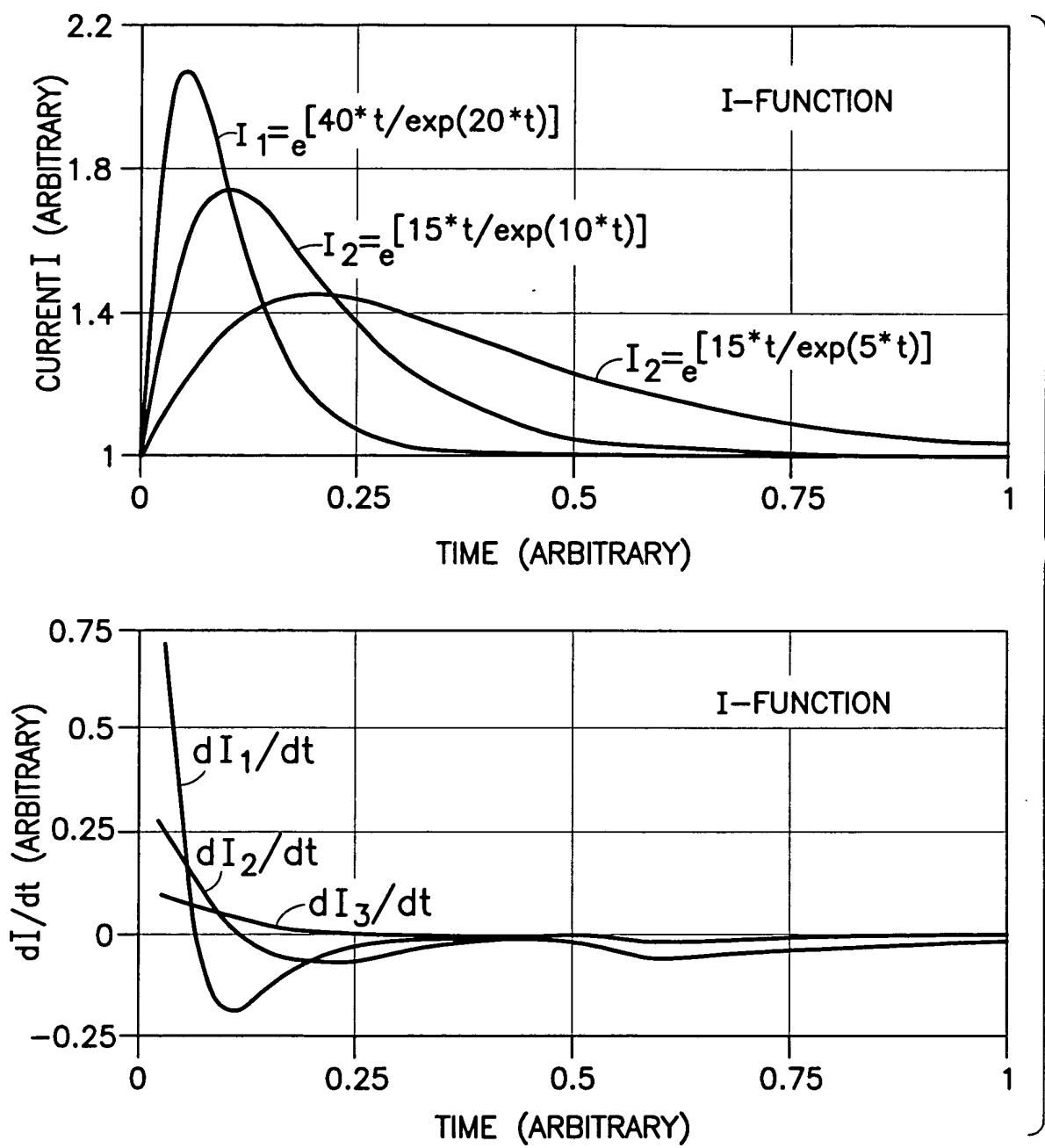


FIG.10

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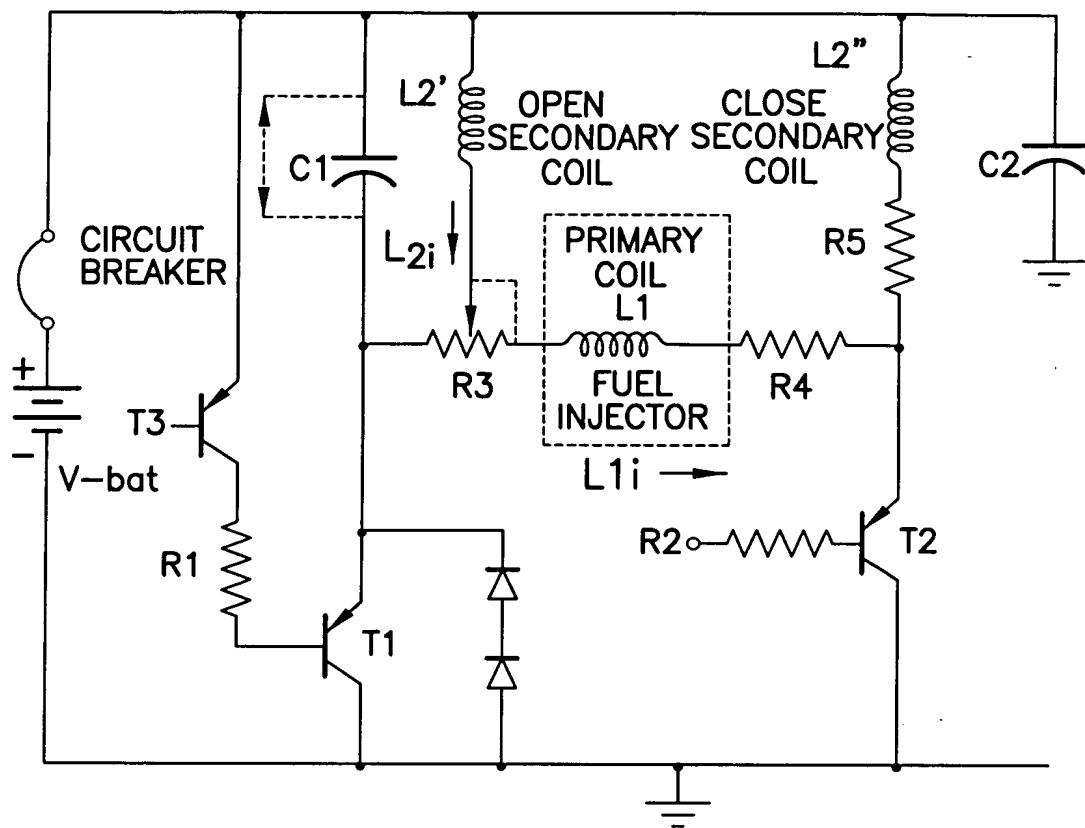


FIG.11A

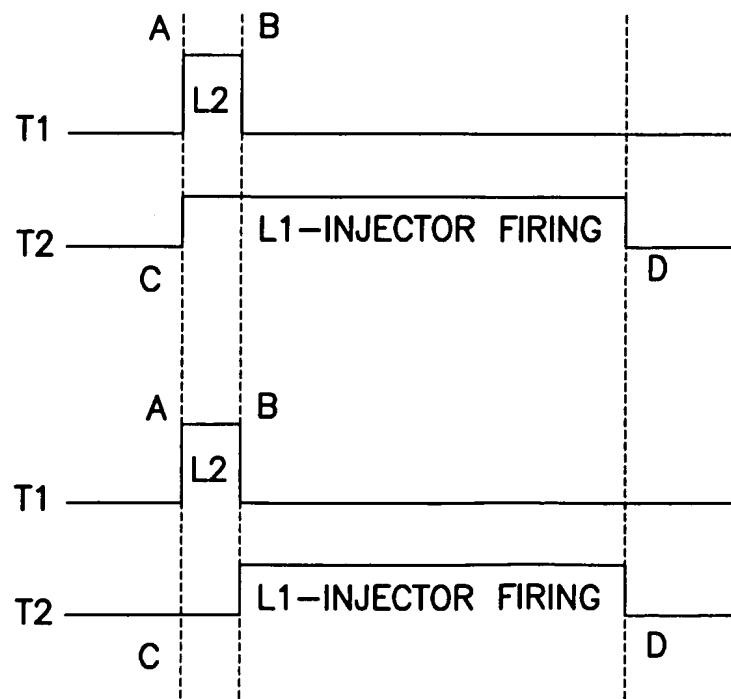


FIG.11B

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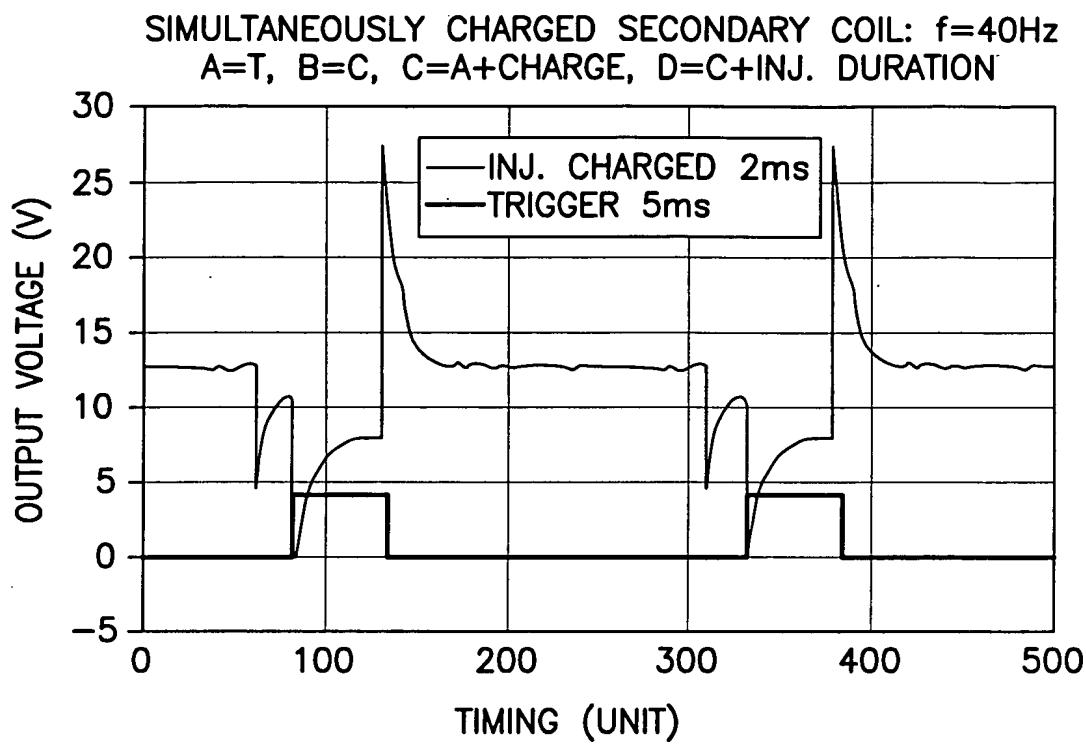


FIG.12A

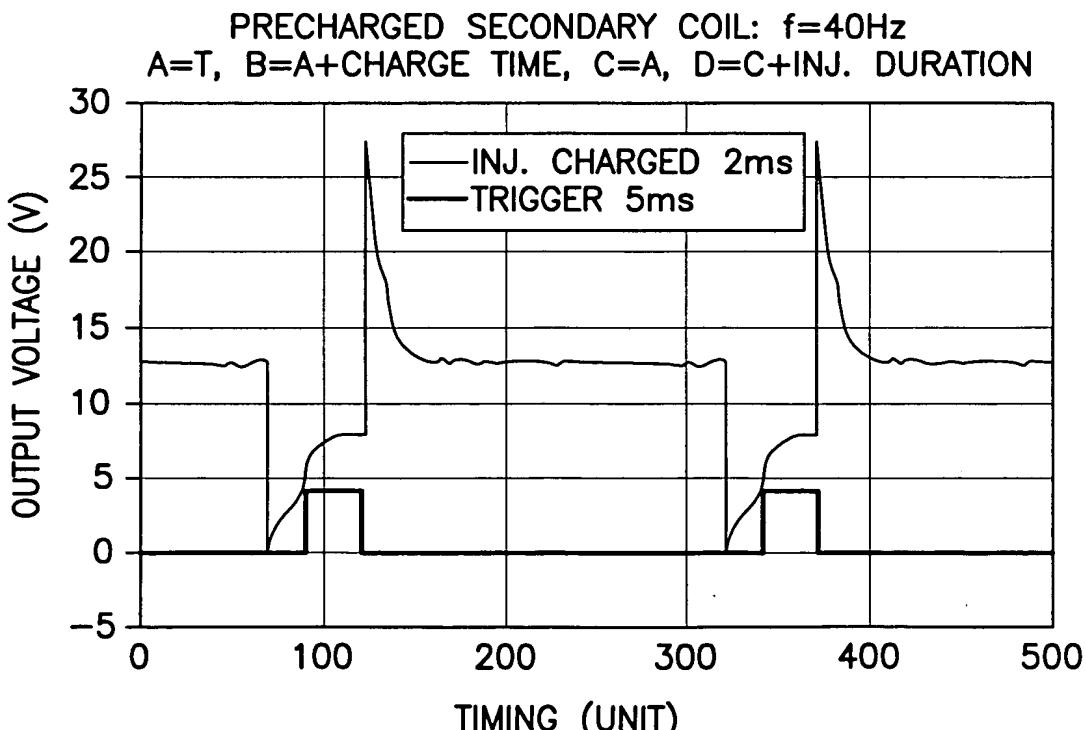


FIG.12B

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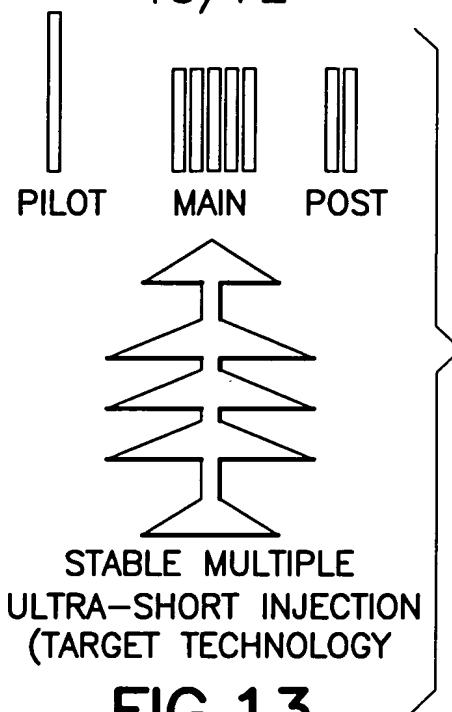


FIG.13

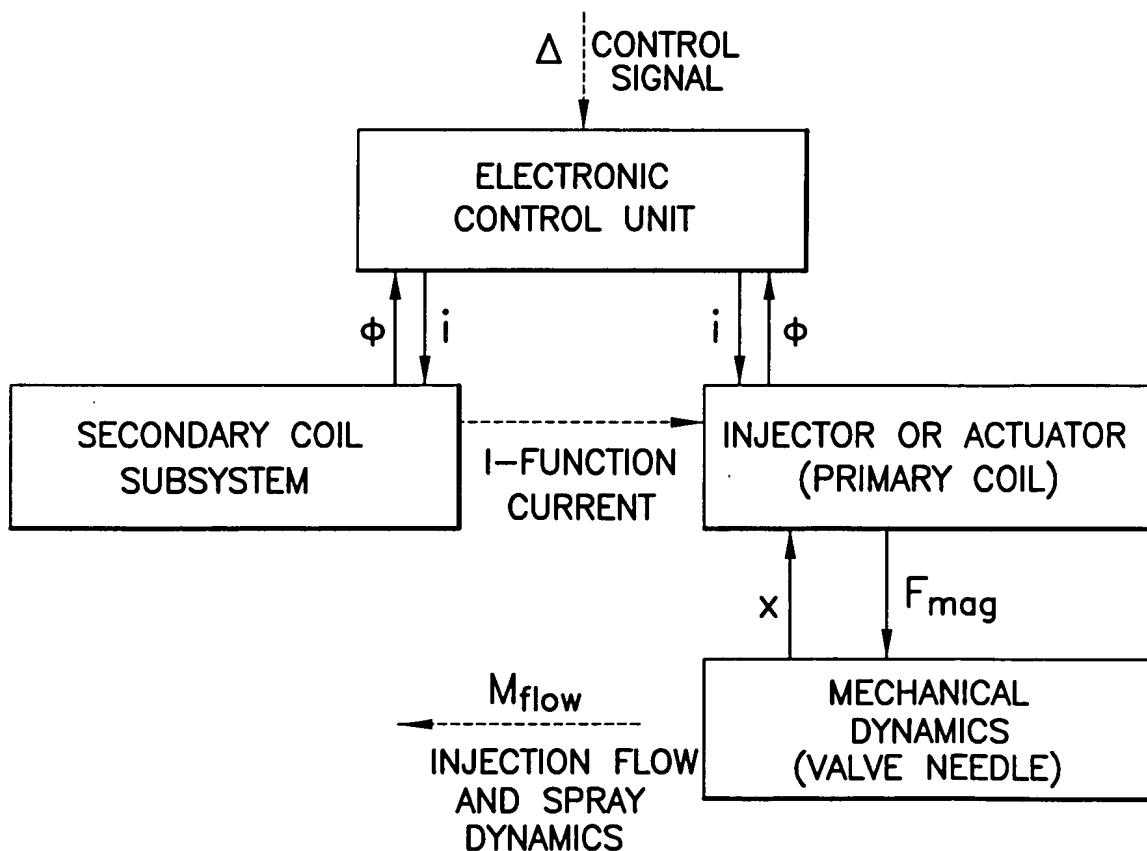


FIG.14

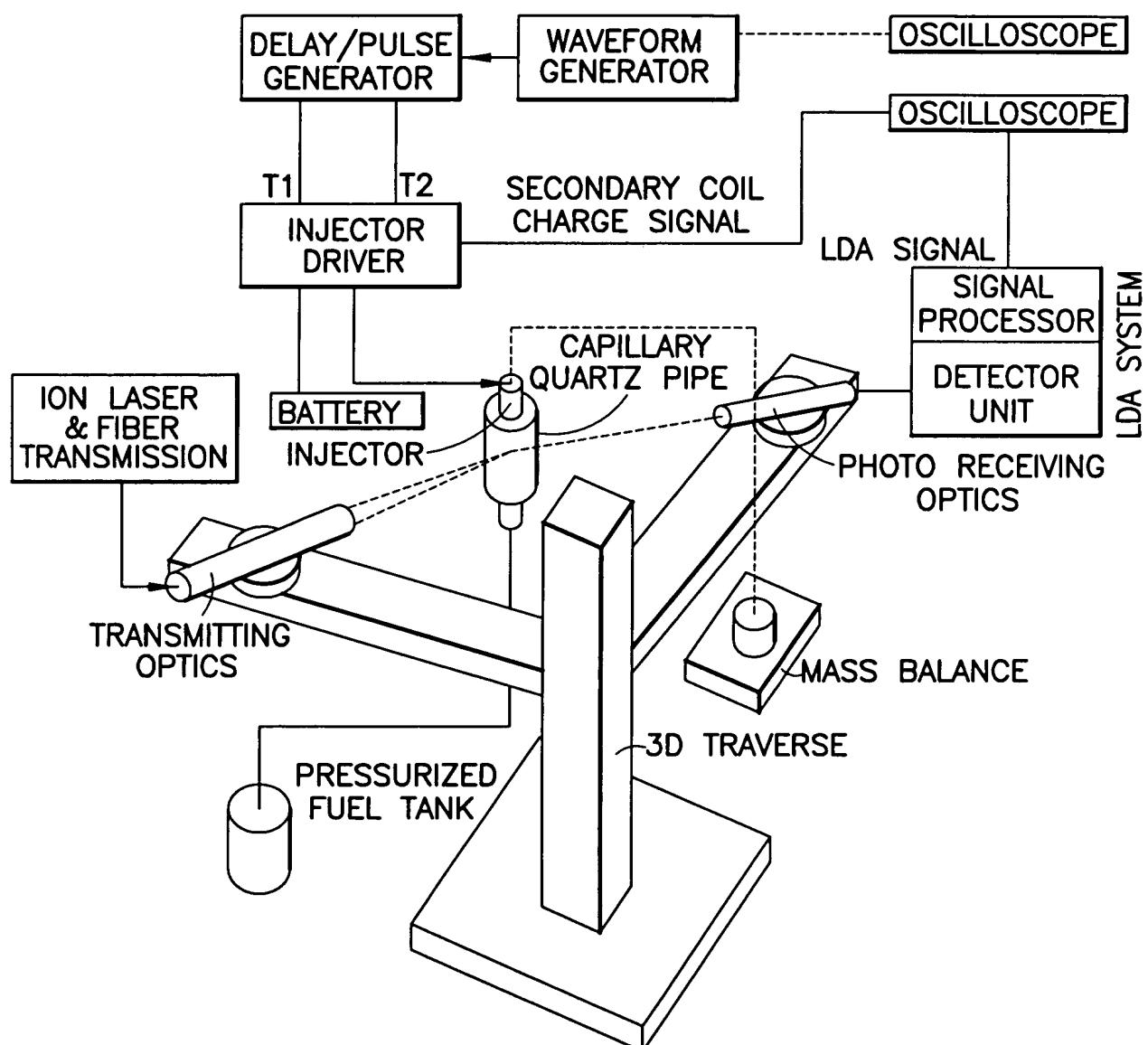


FIG.15

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COMPARISON OF DIFFERENT CHARGING SCENARIOS:
 $P=7.3\text{atm}$, $f=50\text{Hz}$, SC CHARGING 2.0ms

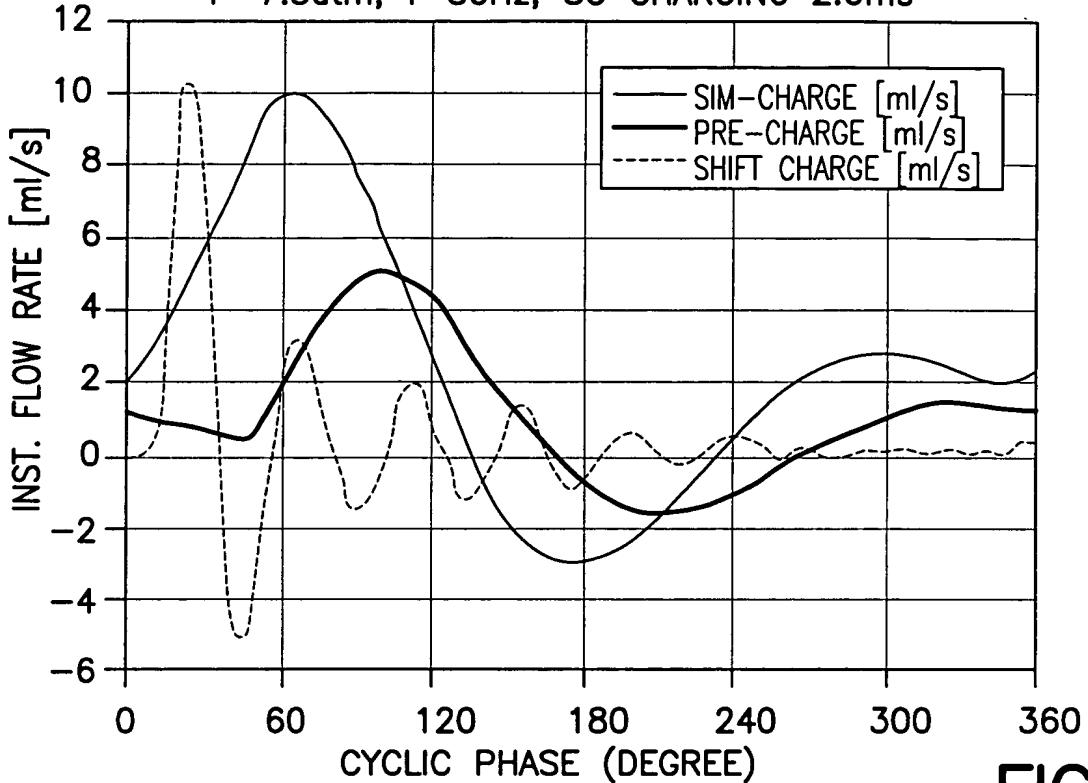


FIG.16A

COMPARISON OF DIFFERENT SC CHARGING SCENARIOS:
 $P=7.3\text{atm}$, $f=50\text{ Hz}$, SC CHARGING 2.0ms, $\tau=3$ & 5ms

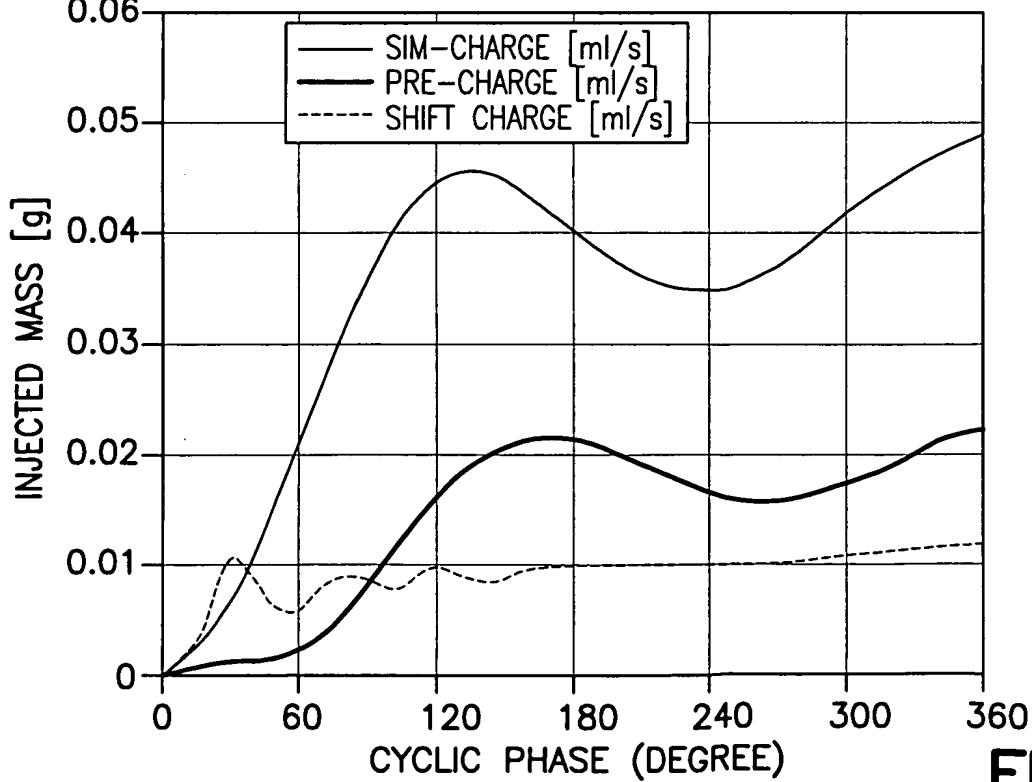


FIG.16B

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SIMULTANIOUSLY CHARGED SC: CHARGING 0.0, 1.0, 1.5
AND 2ms f=50Hz, $\tau=5\text{ms}$, P=7.3atm

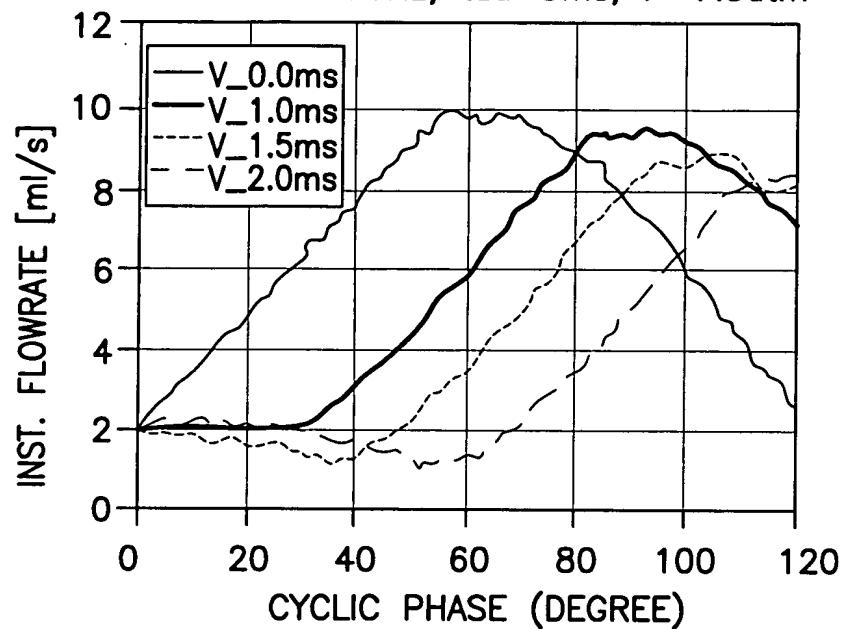


FIG.17A

SIMULTANIUS CHARGE SC: CHARGING 0.0, 1.0, 1.5
AND 2ms f=50Hz, $\tau=5\text{ms}$, P=7.3atm

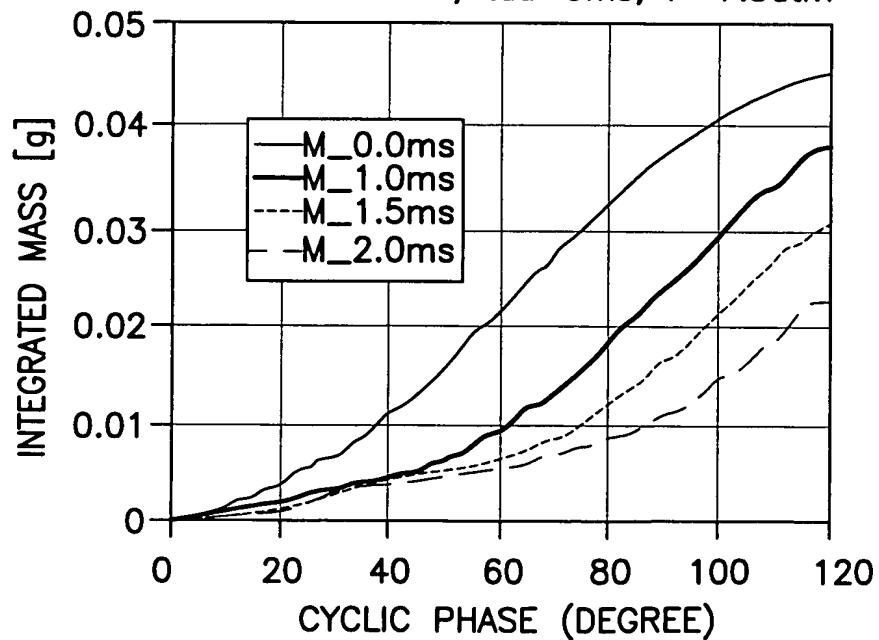


FIG.17B

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PRE-CHARGE SC: CHARGING 0.5, 1.0 AND 1.5ms
 $f=50\text{Hz}$, $\tau=3\text{ms}$, $P=7.3\text{atm}$

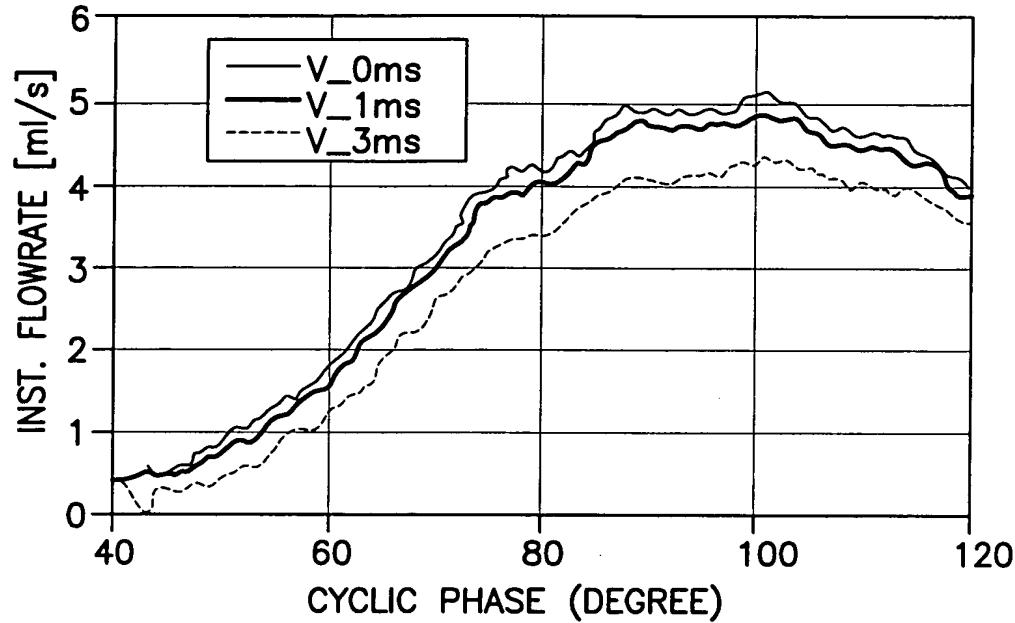


FIG.17C

PRE-CHARGED SC: CHARGING 0.0, 1.5 AND 3.0ms
 $f=50\text{Hz}$, $\tau=3.0\text{ms}$, $P=7.3\text{atm}$

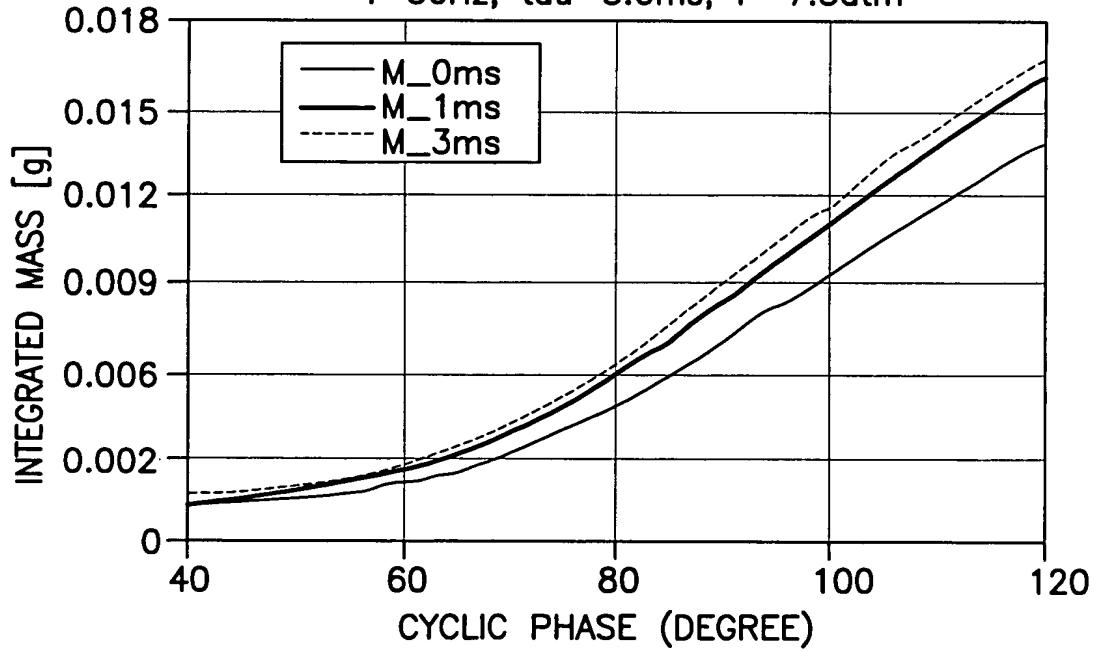


FIG.17D

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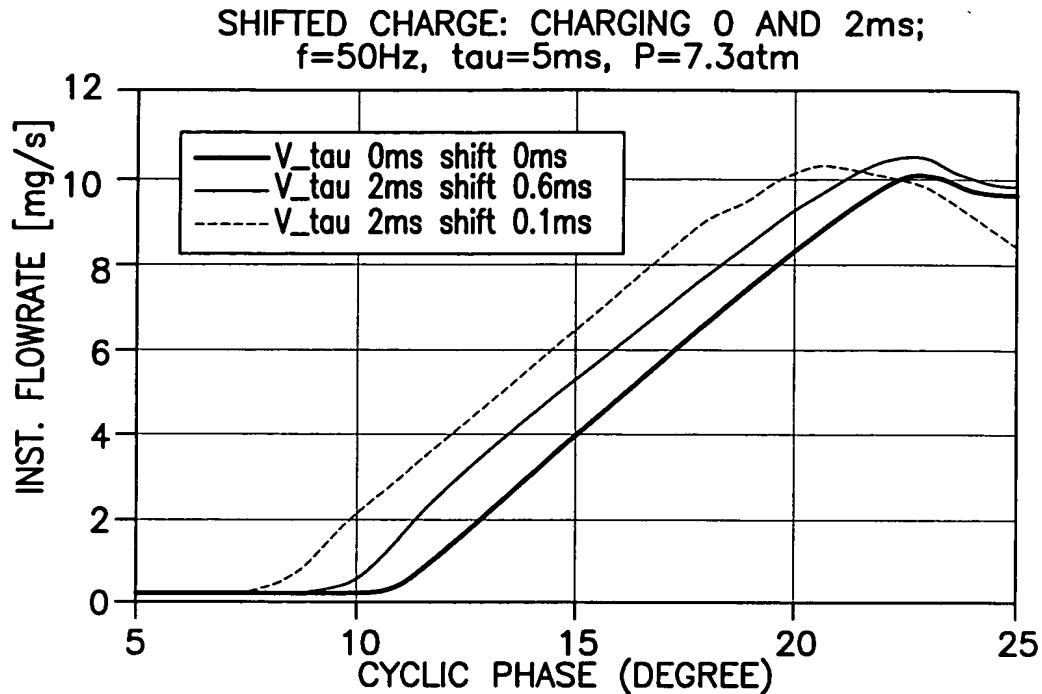


FIG.17E

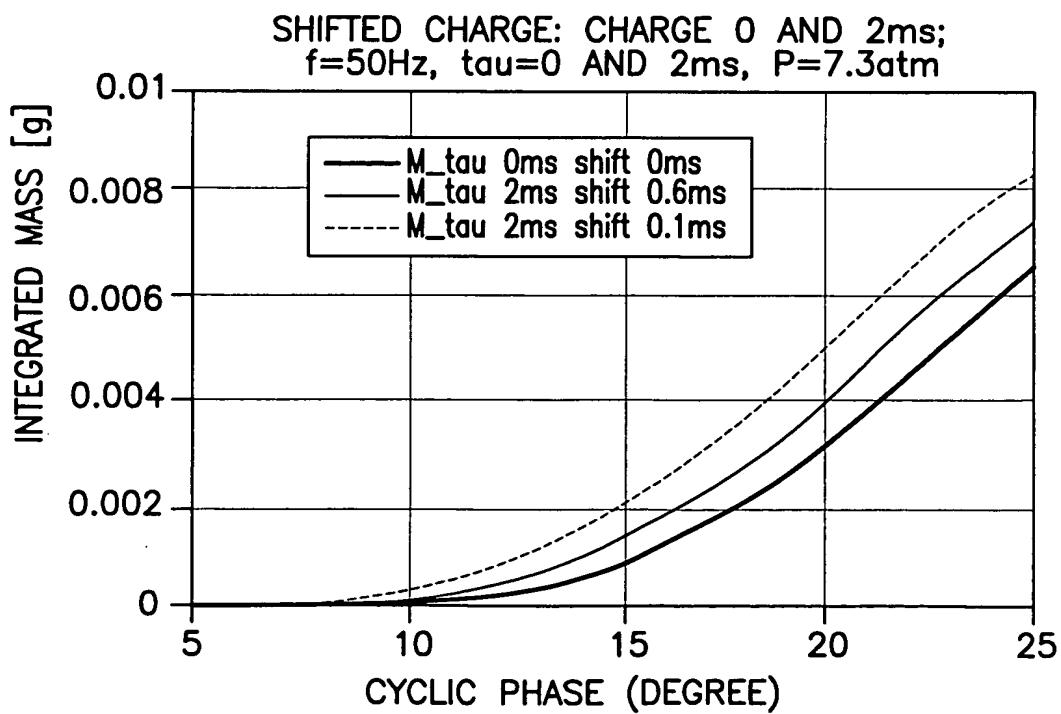


FIG.17F

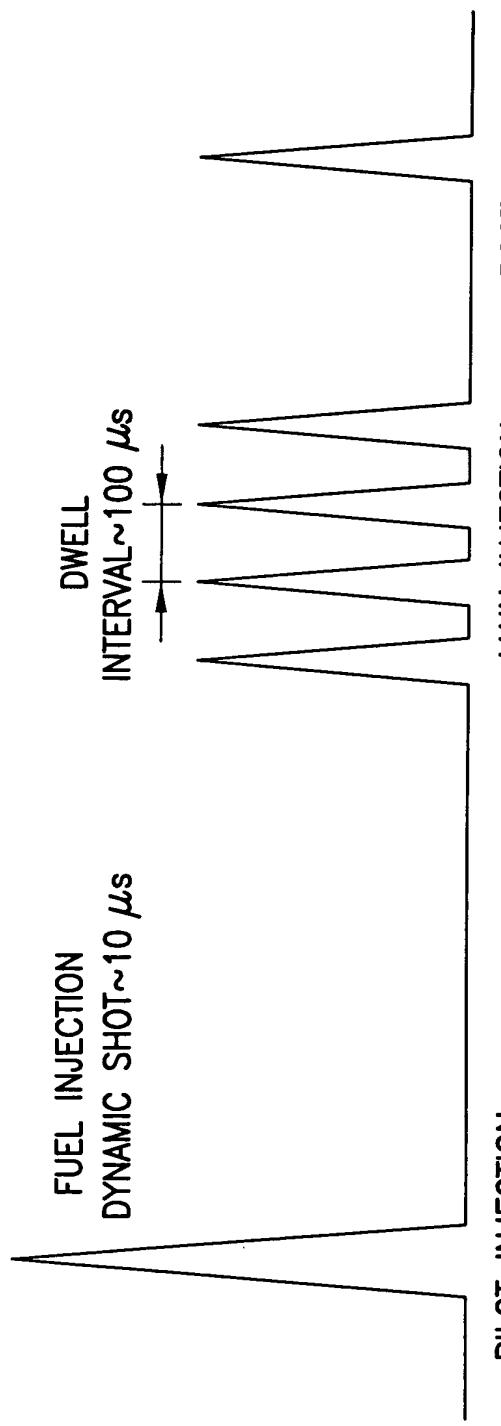


FIG. 18

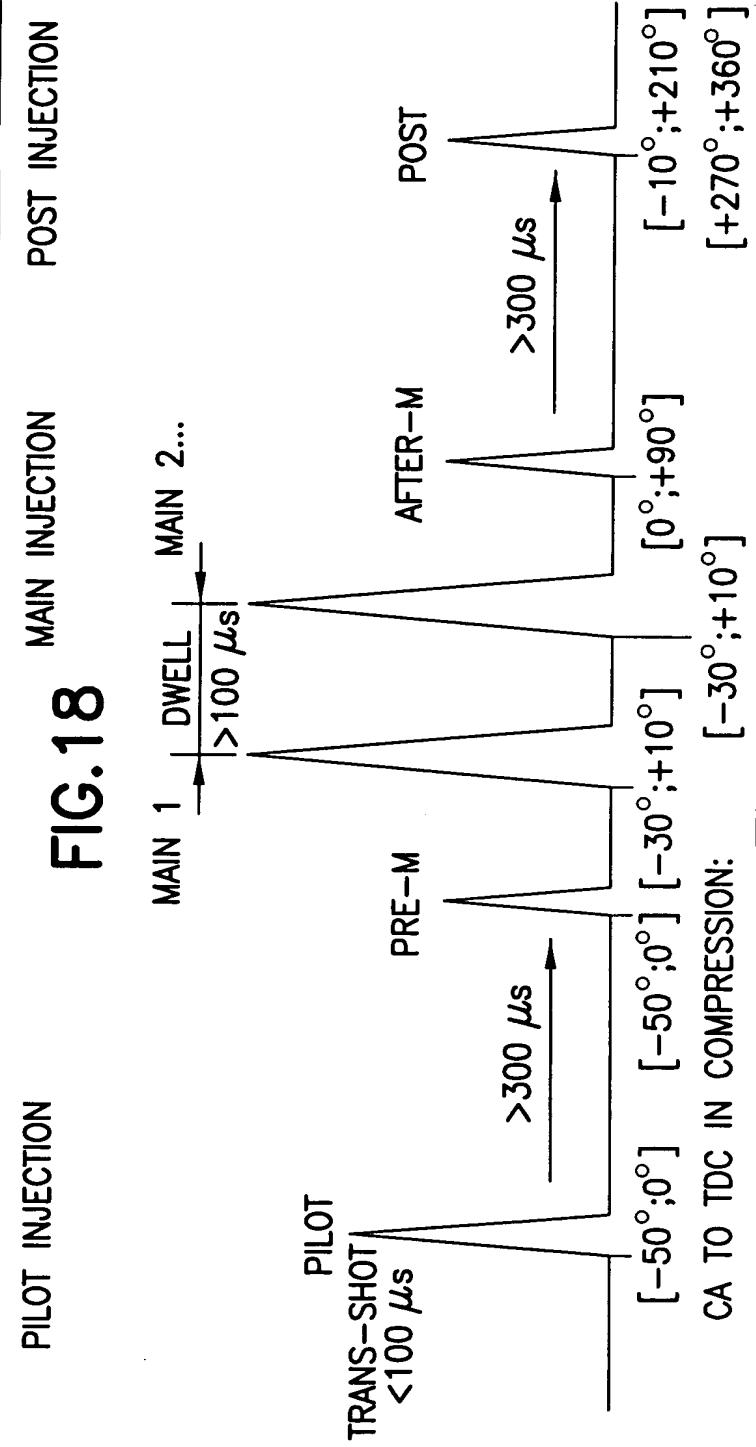


FIG. 19

# INJECTOR	L_mean μ H max	L_mean μ H min	R_mean Ω max	R_mean Ω min	TIME μ sec	L/R FREQ R/L kHz	ω_{21} 0.5*I^2*L/T E_peak W	E_hold 4*I_E_peak W	ω_{22} T22=T21*2 T=R/L_22 μ sec	L_22 μ H kHz	R_22 Ω I_p18A R=L/T
BOSCH ENGINE											
1 I	65.73	65.75	0.45	0.45	146	6.85	72.9	4.7	291.6	3.42	292
2 II	76.24	76.35	0.35	0.45	191	5.24	64.8	5.5	259.2	2.62	381
3 III	68.48	68.41	0.35	0.45	171	5.84	64.8	4.9	259.2	2.92	342
3 IV	69.42	69.58	0.35	0.45	174	5.76	64.8	5.0	259.2	2.88	348
ADDT:											
4 V	79.79	79.85	0.35	0.45	200	5.01	64.8	5.7	259.2	2.51	399
5 VI	84.75	84.84	0.35	0.45	212	4.72	64.8	6.1	259.2	2.36	424
6 VII	79.69	79.69	0.35	0.45	199	5.02	64.8	5.7	259.2	2.51	398

FIG.20

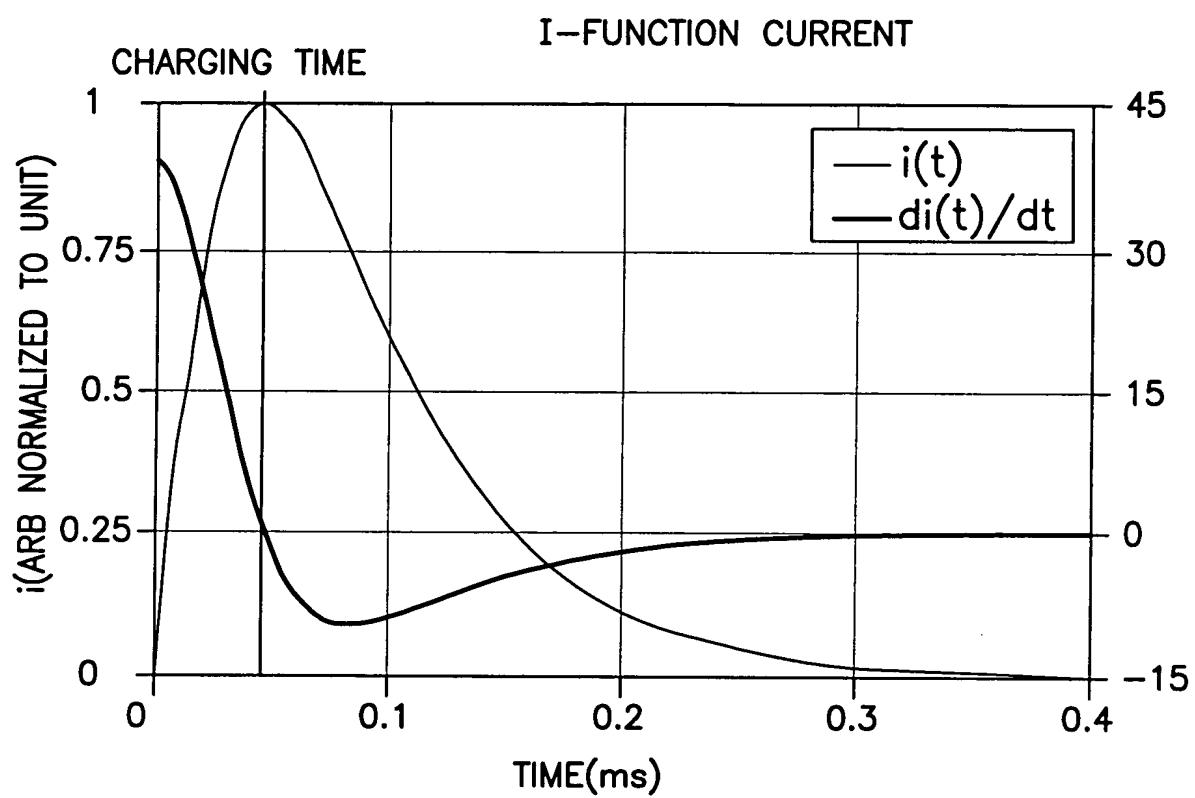


FIG.21

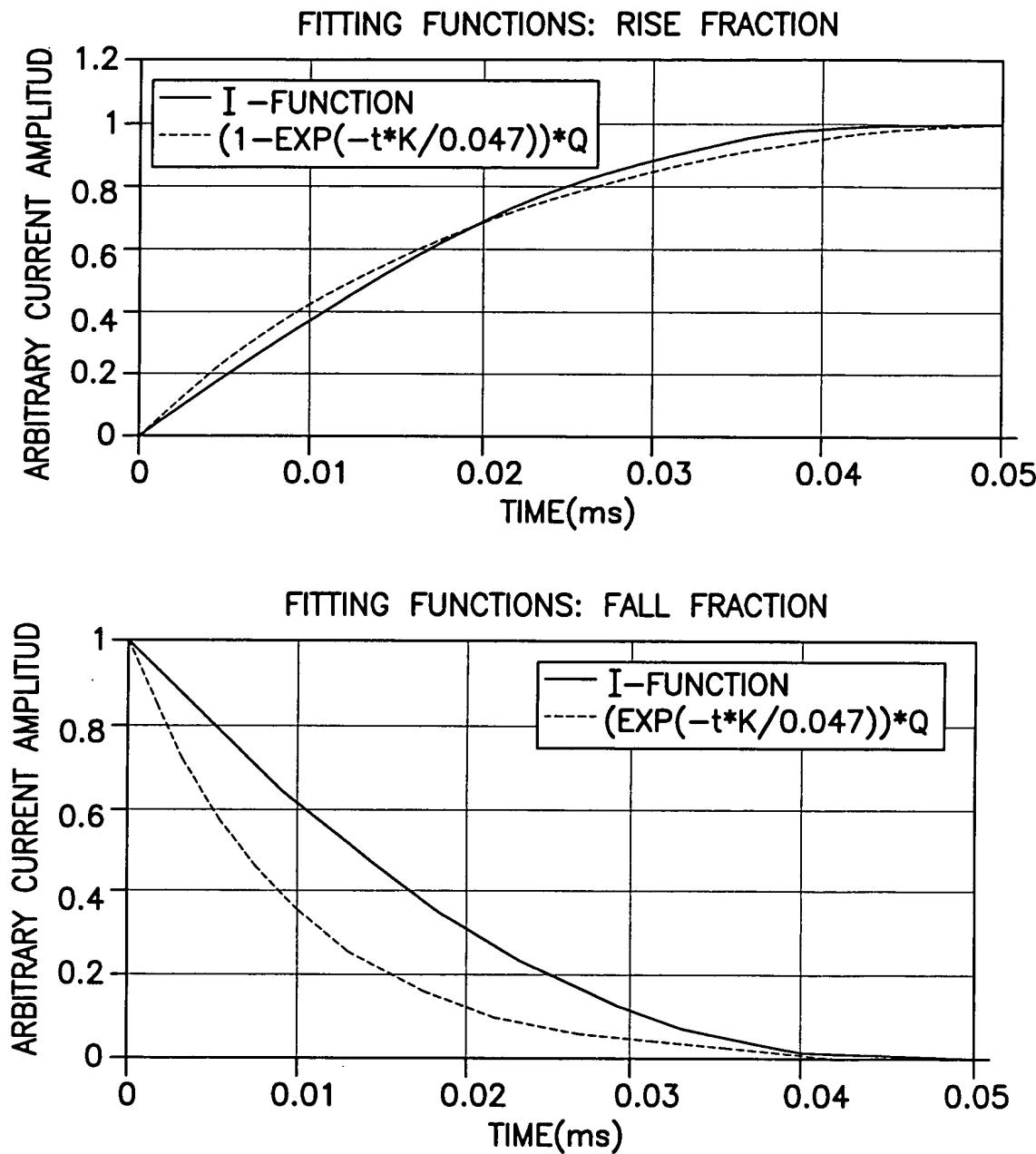


FIG.22

FIG.23A

No.	PARAMETER	CALCUL FORMULA	DIMENSION	VALUE	CONTROL	DEVICE/UNIT
1	INDUCTANCE	L, MEASURED	μH	#REF!	L/R METER IB	BOSCH INJECTORI
2	RESISTANCE	R, MEASURED	Ω	#REF!	MUTIMETER	BOSCH INJECTORI
3	T-RESPONCE	L/R	μs	#REF!	HP INFINUM SCOPE 500 MHz, 1GSa/s	BOSCH PROFILE
4	F-RESPONCE	R/L	kHz	#REF!	HP INFINUM SCOPE 500 MHz, 1GSa/s	BOSCH PROFILE
5	CYCLE [Hz]	CONSIDERED	DEGREE $\frac{\text{ms}}{\text{pts}}$	360 30.0 16000	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	INJECTOR SOLENOID PROGRAM
6	P INJECTION OFFSET "-X deg BTDC"	CONSIDERED START	DEGREE $\frac{\text{ms}}{\text{pts}}$	157.5 13.13 7000	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	INJECTOR SOLENOID PROGRAM
7	M INJECTION OFFSET "TDC"	CONSIDERED	DEGREE $\frac{\text{ms}}{\text{pts}}$	180 15.00 8000	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	INJECTOR SOLENOID PROGRAM

8	P_M_INTERVAL	P_off - M_off X BTC	DEGREE μ s pts	22.5 1875 1000	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	INJECTOR SOLENOID PROGRAM
9	NORMAL INJECTION "-X deg BTDC"	max 2.2 ms	DEGREE μ s pts	26.4 2200 1173	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	INJECTOR SOLENOID PROGRAM
10	P_DURATION= M_DURATION	CONSIDERED	DEGREE μ s pts	7.2 600 320	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	INJECTOR SOLENOID PROGRAM
11	P_M_dwell	(P_off-M_off)-P_dur	DEGREE μ s pts	15 1275 680	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	SOLENOID INJECTOR PROGRAM
12	TOTAL INJECTION DURATION	P_dur+dwell+M_d_off	DEGREE μ s pts	30 2475 1320	HP/AGILENT 33120A 15 MHz WAVEGENERATOR	INJECTOR SOLENOID PROGRAM

FIG.23B

FIG.23

FIG.23A

FIG.23B

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SCALES	I[A]	2.0	t[ms]	0.200
	L[mm]	9.8	L[mm]	14.1
	I/L[A/mm]	0.204t/L[ms/mm]		0.01418

FIRST SHOT [us]	600	POINTS	320
SECOND SHOT [us]	600	POINTS	320
DWELL INTERVAL [us]	1275	POINTS	680

PROFILE MI_33_2x600_1275_SC	PHASE	τ_{lin} [mm]	I_{lin} [mm]	τ_{abs} [ms]
τ_{off} [pts]				
7000	A	0.0	0.0	0.000
157.5°	B	I-FUNCTION	FIRST PEACK	0.175
FIRST SHOT	C	3.6	56.2	0.051
	D	CALCULATION	56.0	0.280
	E	I-FUNCTION	0.0	0.094
	CD_osc		TOTAL	0.600
		4.5	2.8	0.128
τ_{off} [pts]				
8000	A	0.0	0.0	0.000
180°	B	I-FUNCTION	FIRST PEACK	0.175
SECOND SHOT	C	3.6	56.2	0.051
	D	CALCULATION	56.0	0.280
	E	I-FUNCTION	0.0	0.094
	CD_osc		2.8	0.128

FIG.24A

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T[pts]	16000
V_arb[-]	1
R[Ohm]	0.45
T[ms]	30.0

FIG.24A

FIG.24B

FIG.24

TOTAL pts 320 NUMBER OF SINE CYCLE
 exp_rise 9.36
 exp_fall 9.60

5

I_abs[A]	pts[-]	I_arb[-]	V_abs[V]	$\Delta\tau$ _pts[-]	ΔI _arb[-]	ΔV _abs[V]
0.00	7000	0.000	0.000	0	0.000	0.000
17.80	7093	1.000	8.010	93	1.000	8.010
11.46	7121	0.644	5.159	27	-0.356	-2.851
11.42	7270	0.642	5.141	149	-0.002	-0.018
0.00	7320	0.000	0.000	50	-0.642	-5.141
			TOTAL	320		
0.57	61	0.032	0.257			
0.00	8000	0.000	0.000	0	0.000	0.000
17.80	8093	1.000	8.010	93	1.000	8.010
11.46	8121	0.644	5.159	27	-0.356	-2.851
11.42	8270	0.642	5.141	149	-0.002	-0.018
0.00	8320	0.000	0.000	50	-0.642	-5.141
			TOTAL	320		
0.57	61	0.032	0.257			

FIG.24B

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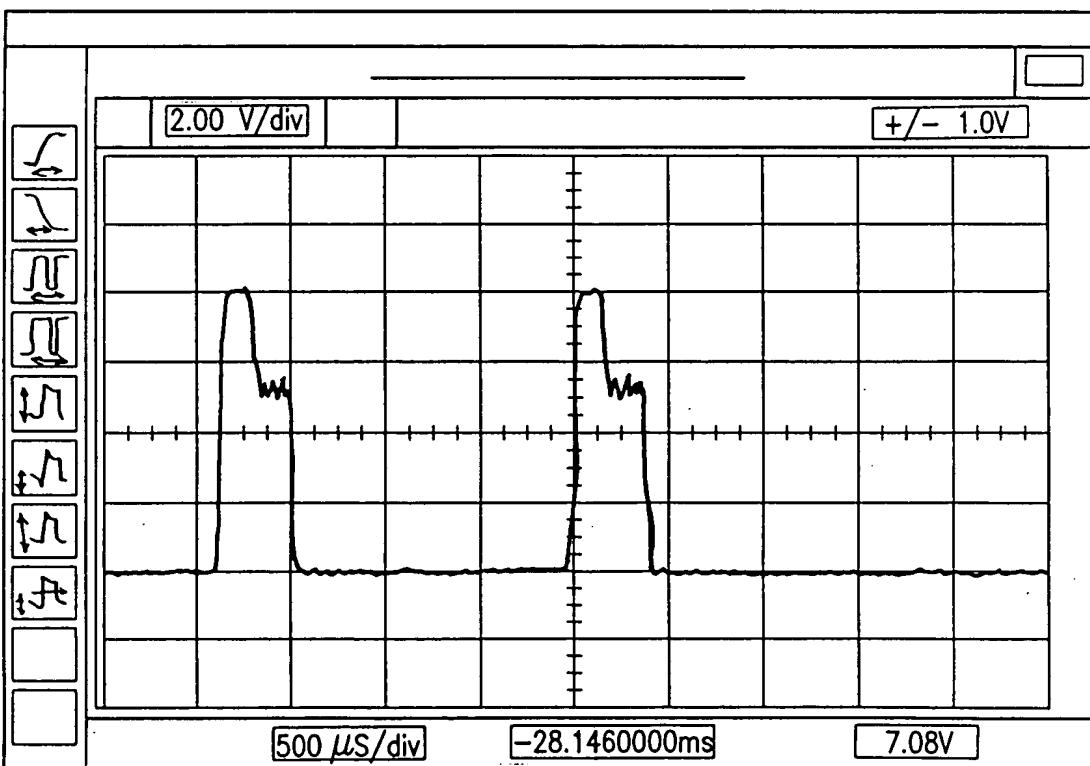
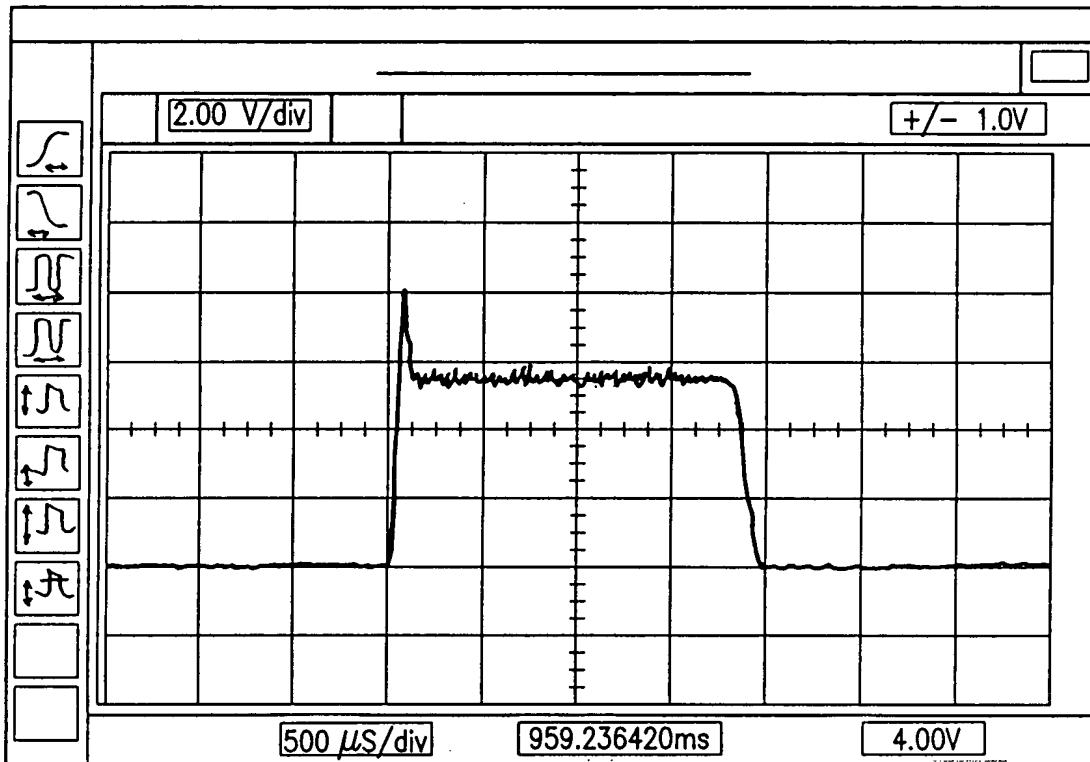


FIG.25

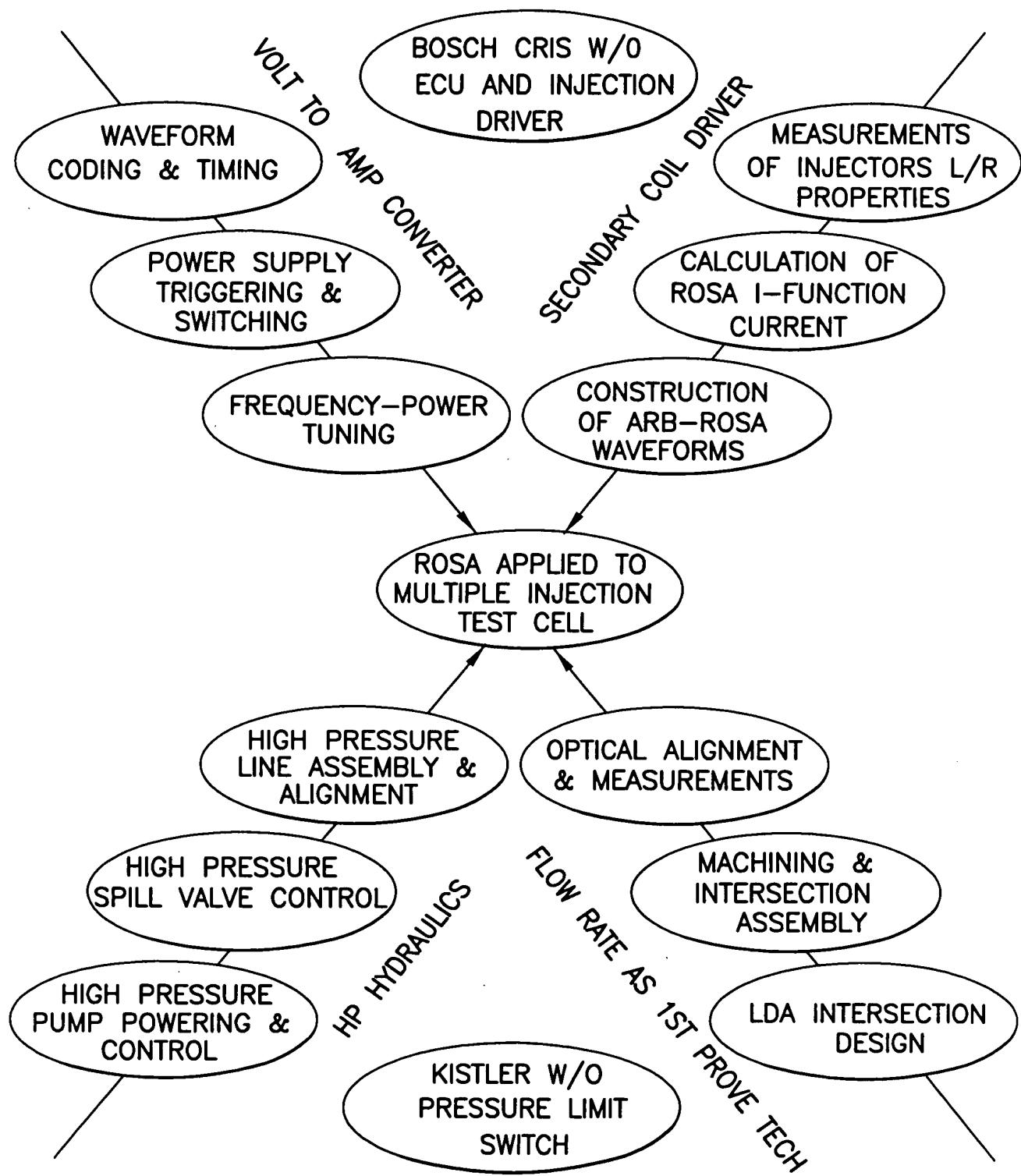


FIG.26

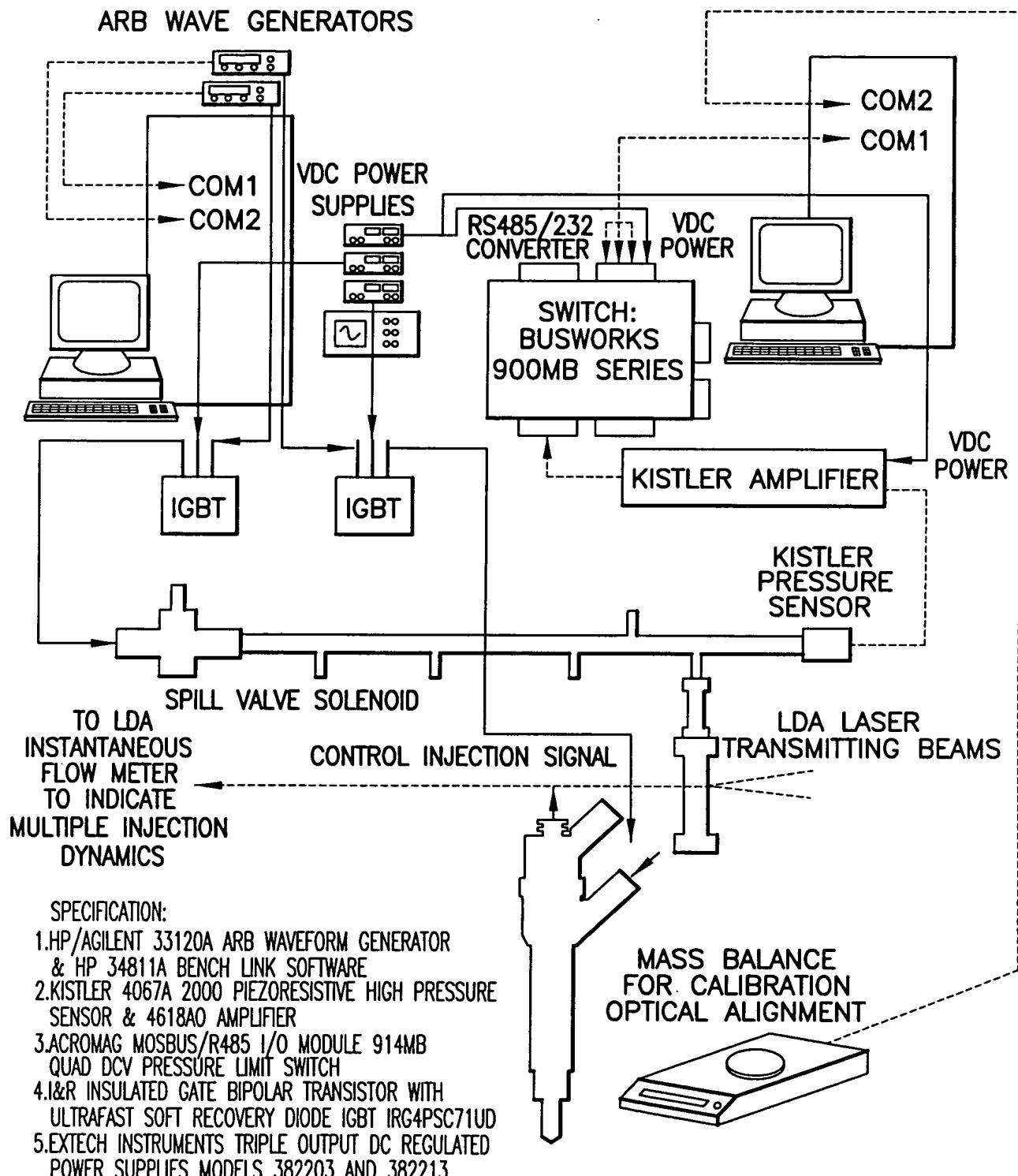


FIG.27

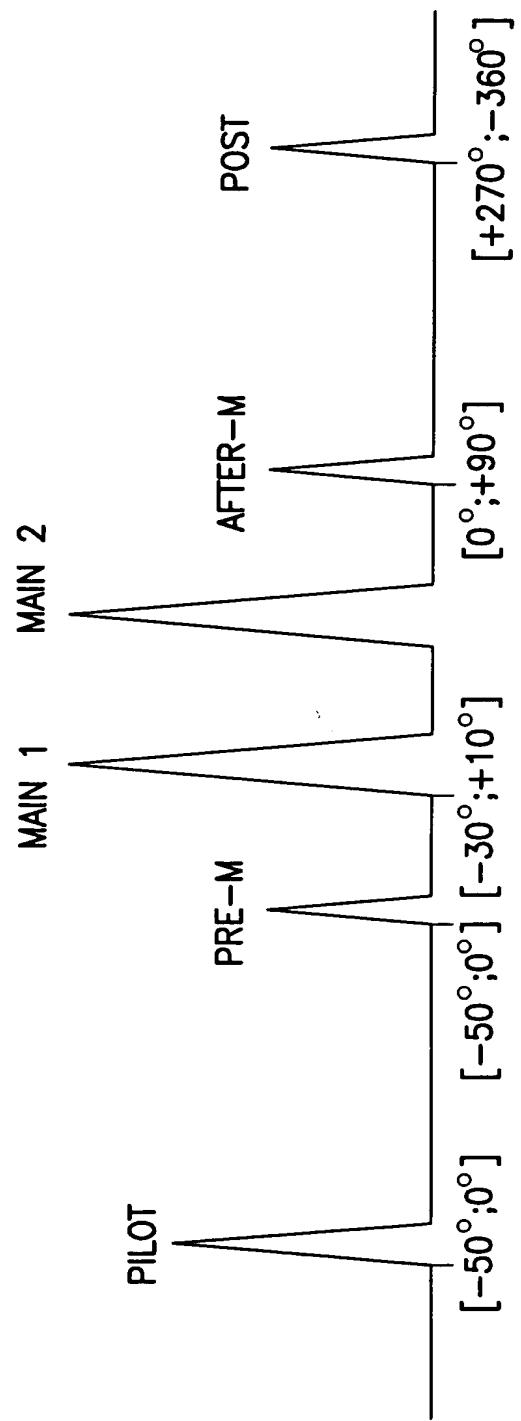


FIG.28

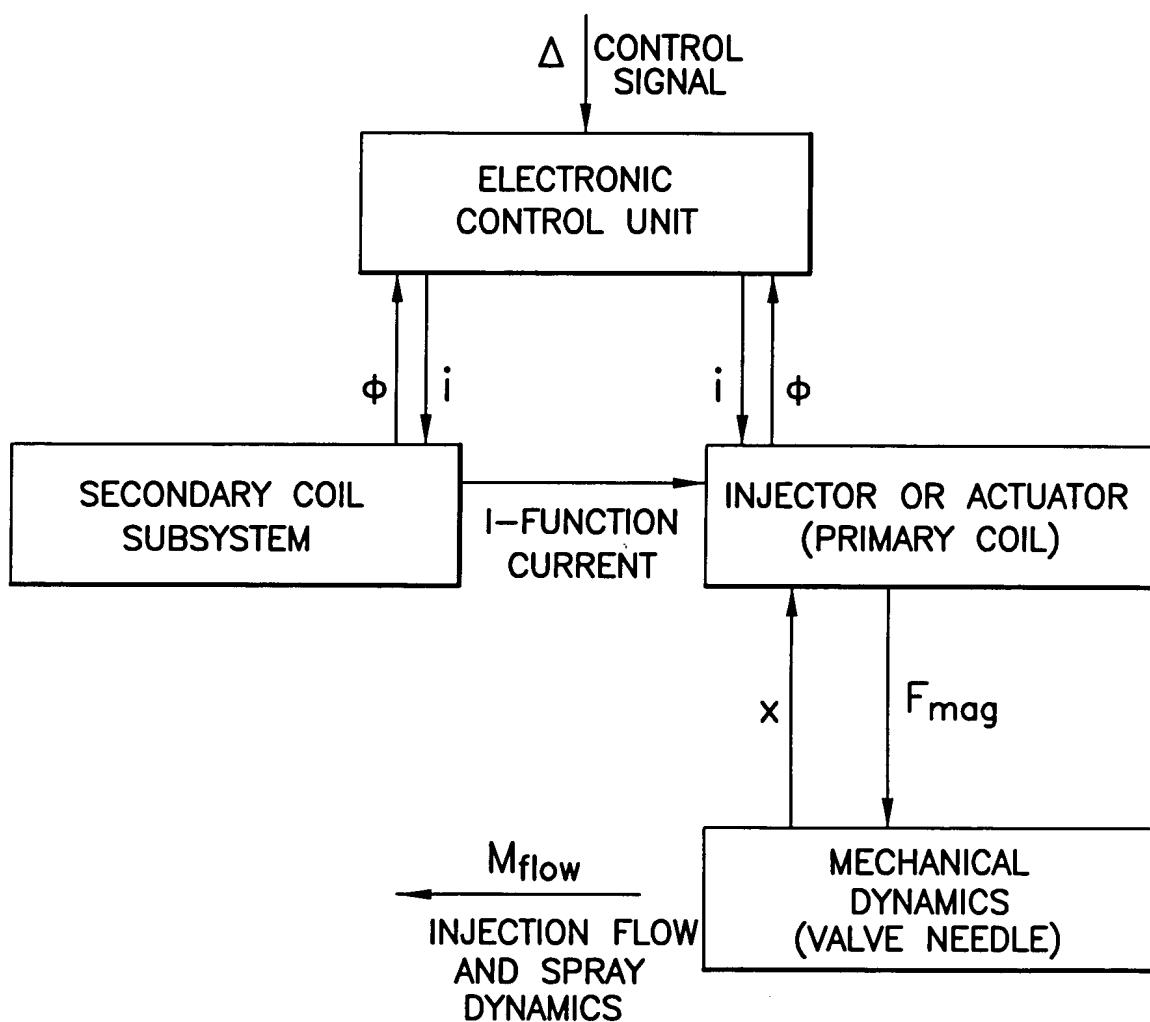


FIG.29

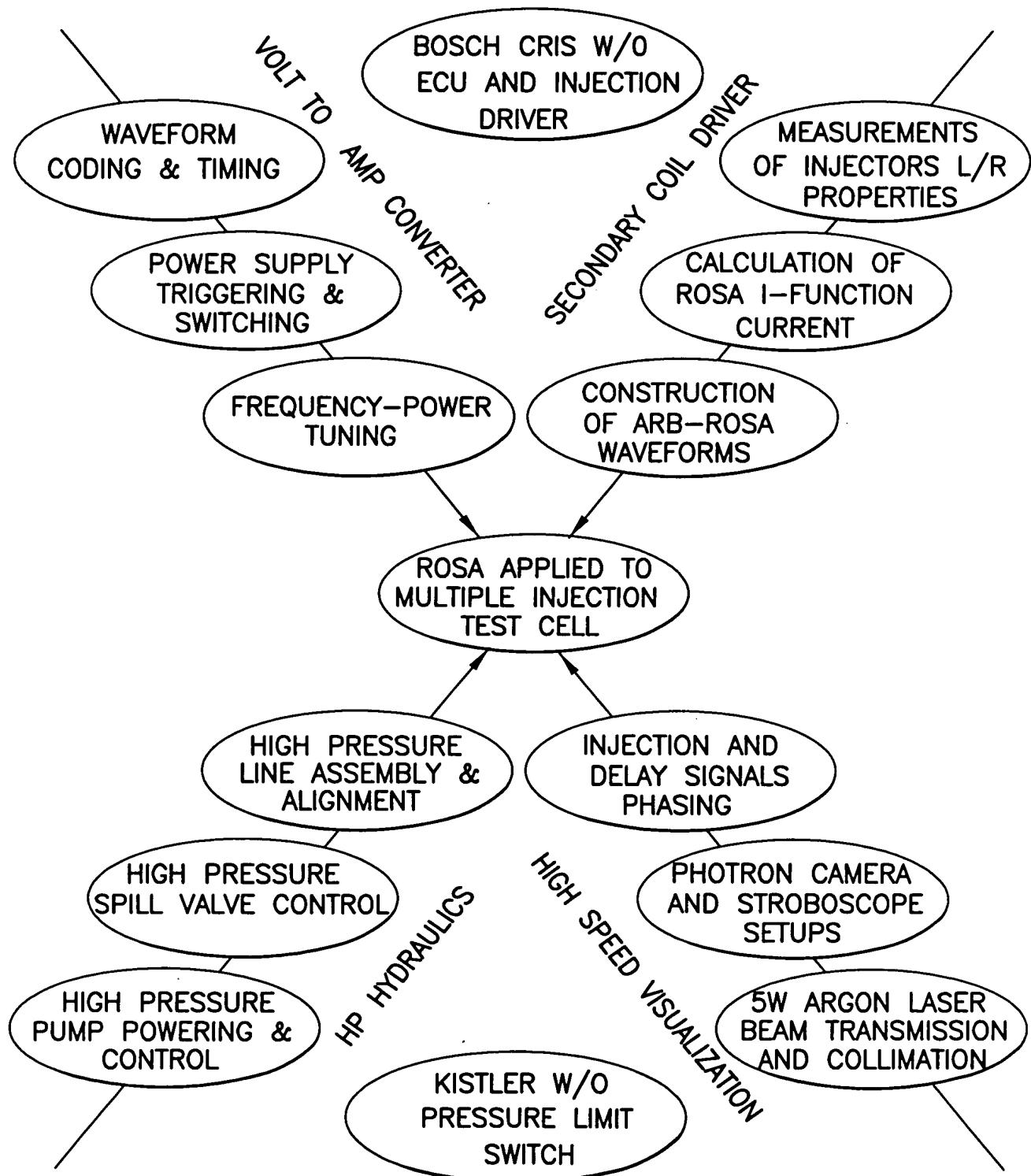


FIG.30

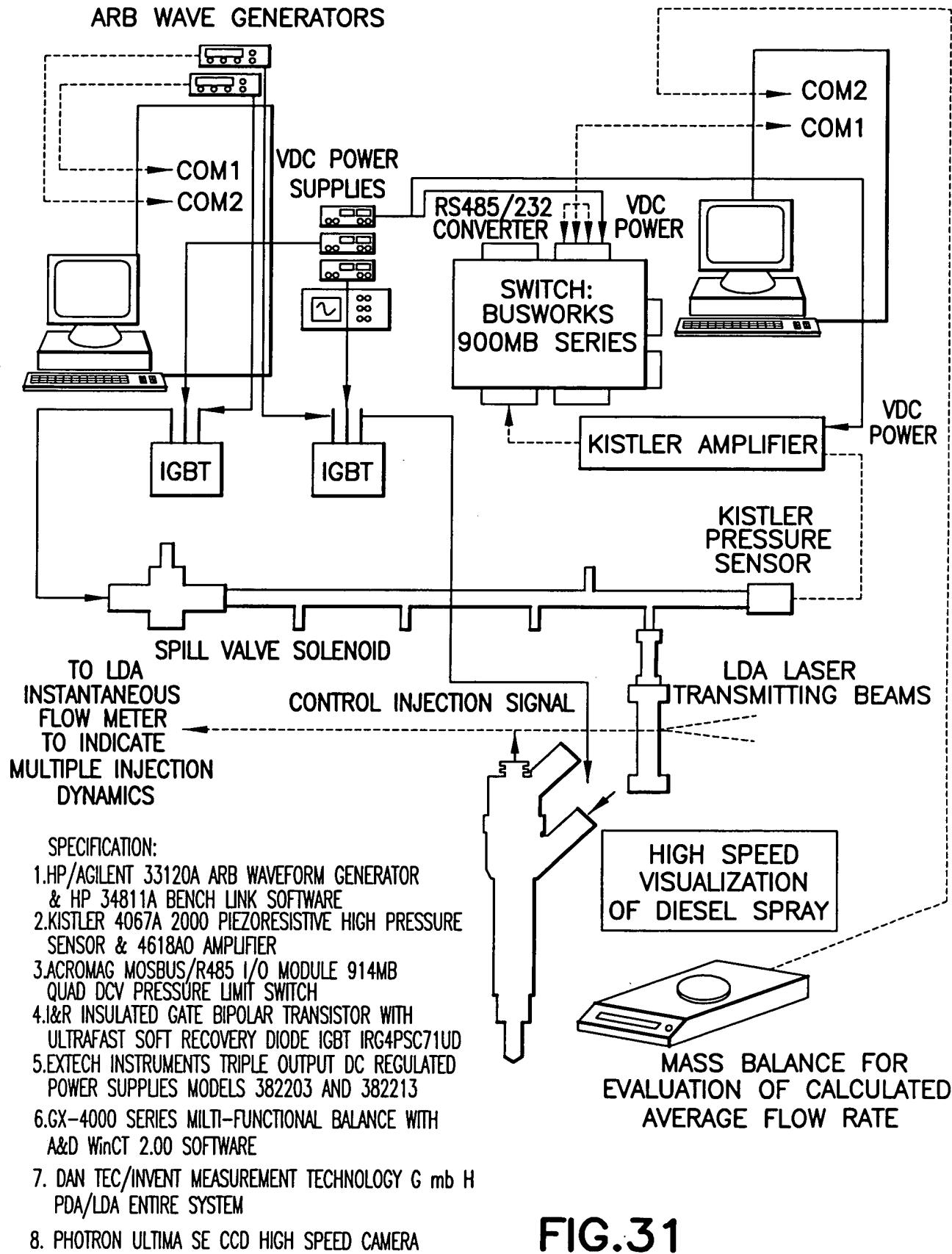


FIG.31

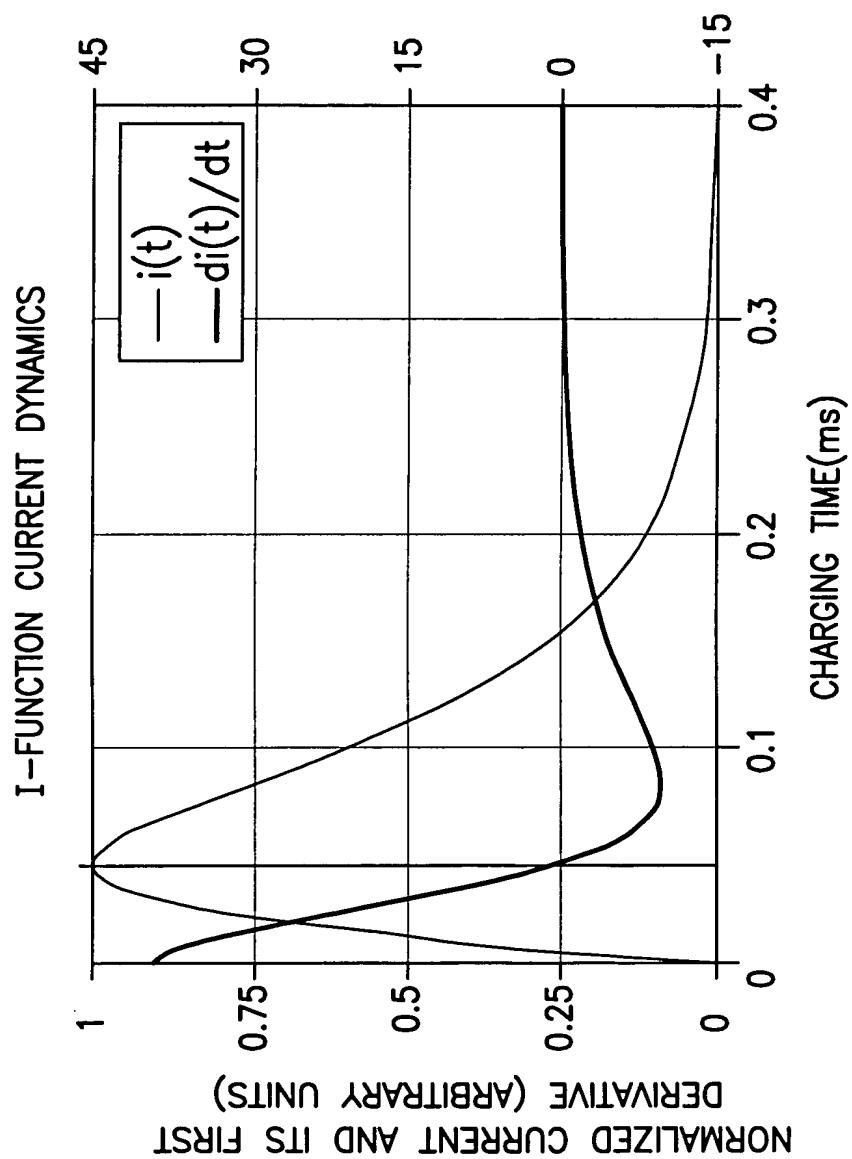


FIG.32

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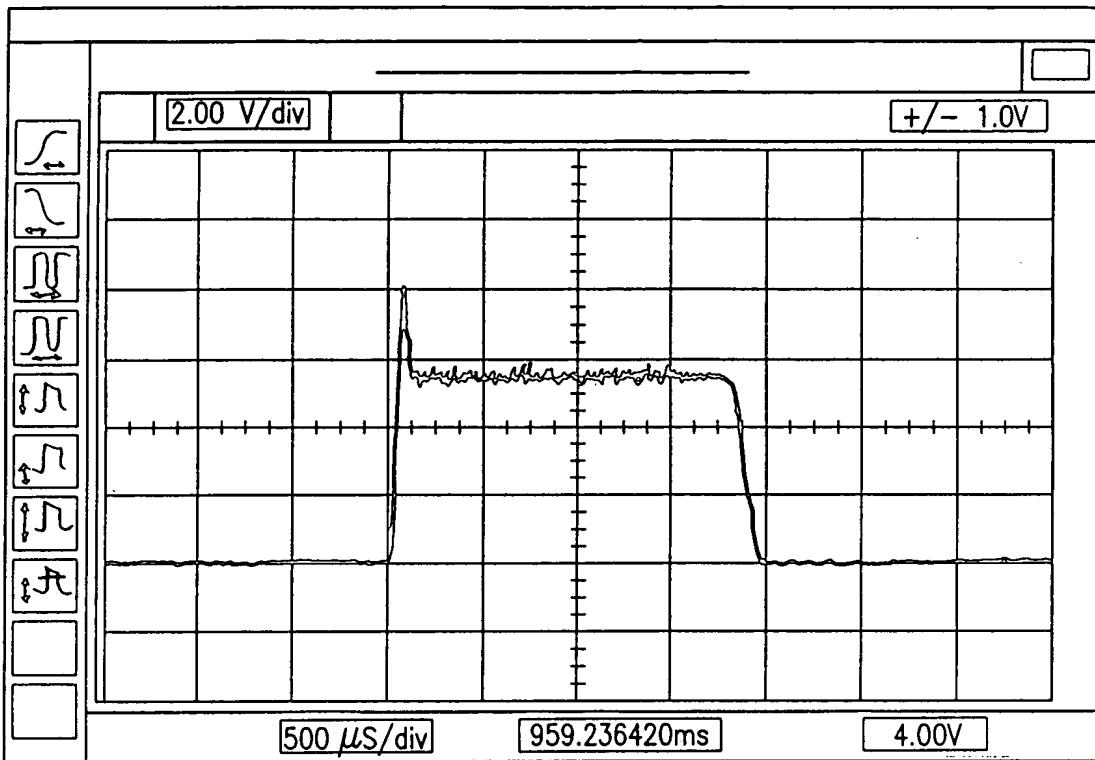


FIG.33

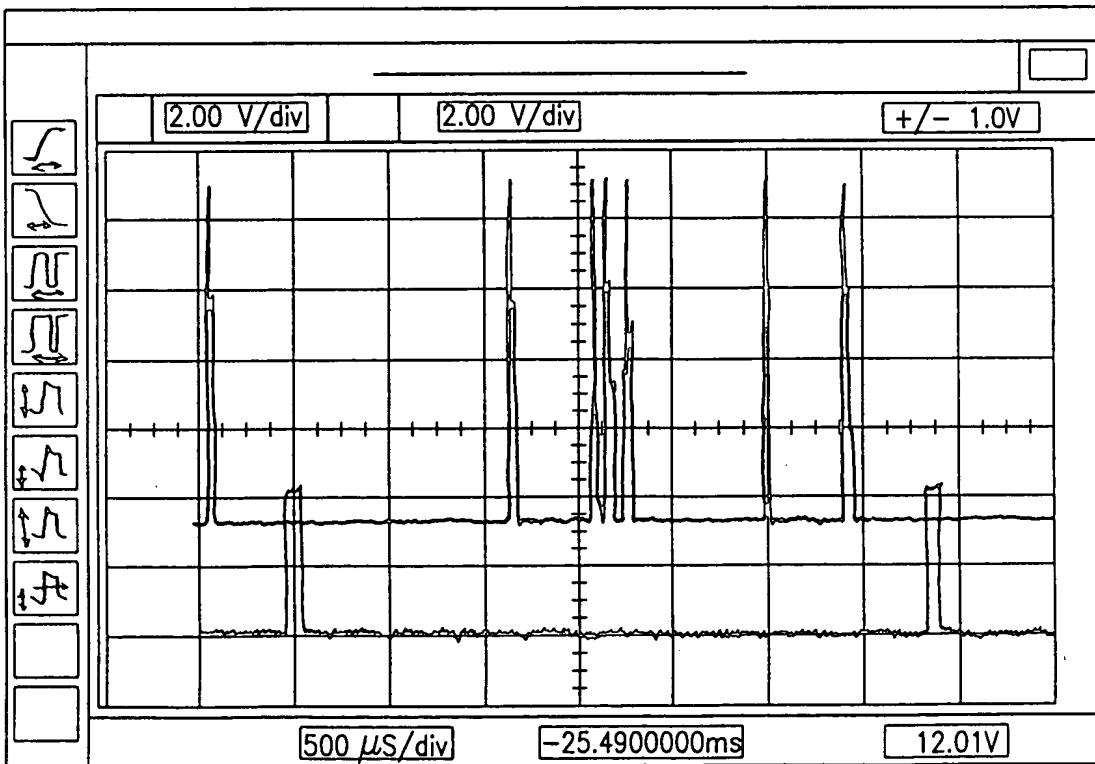


FIG.34

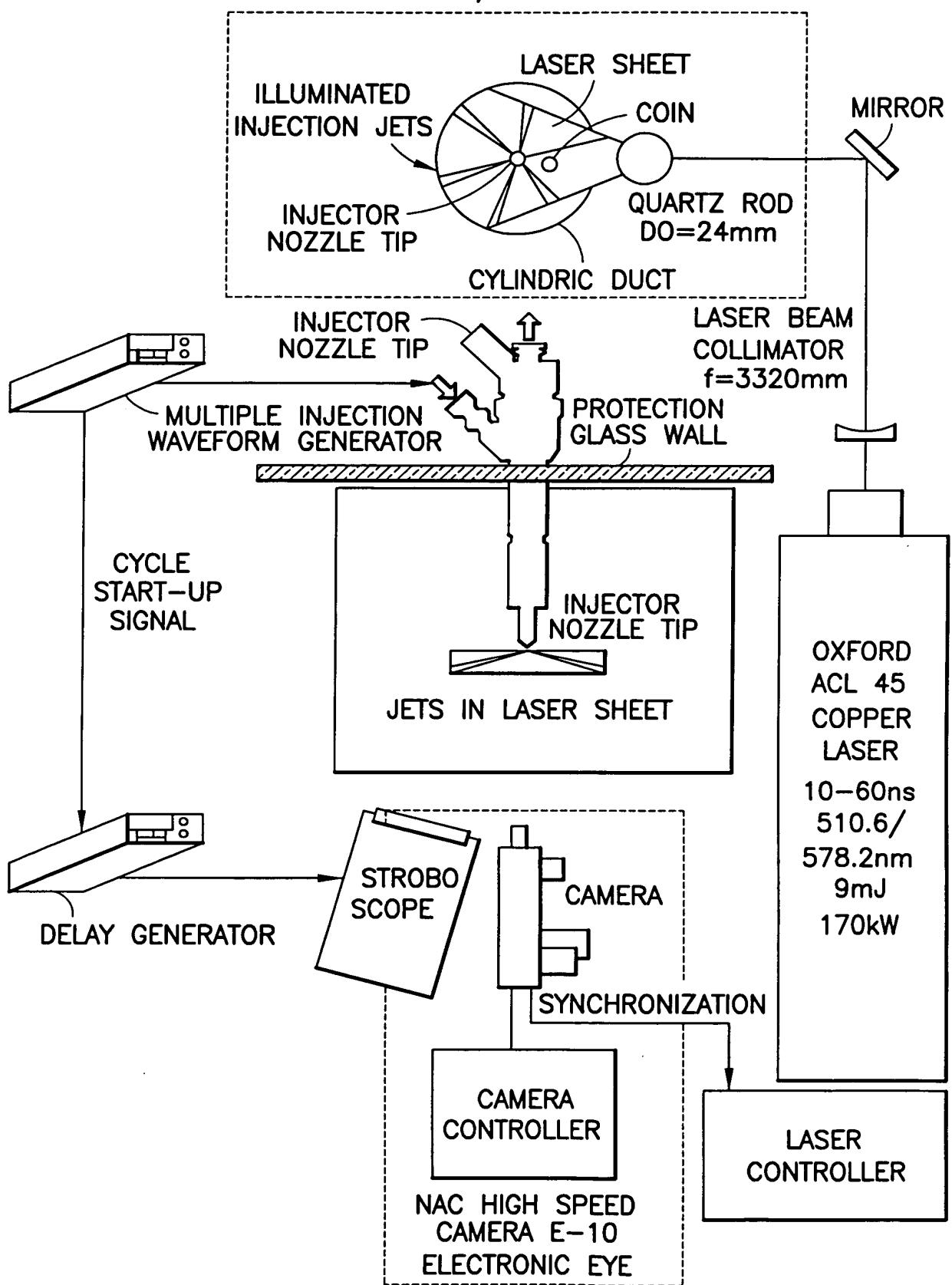
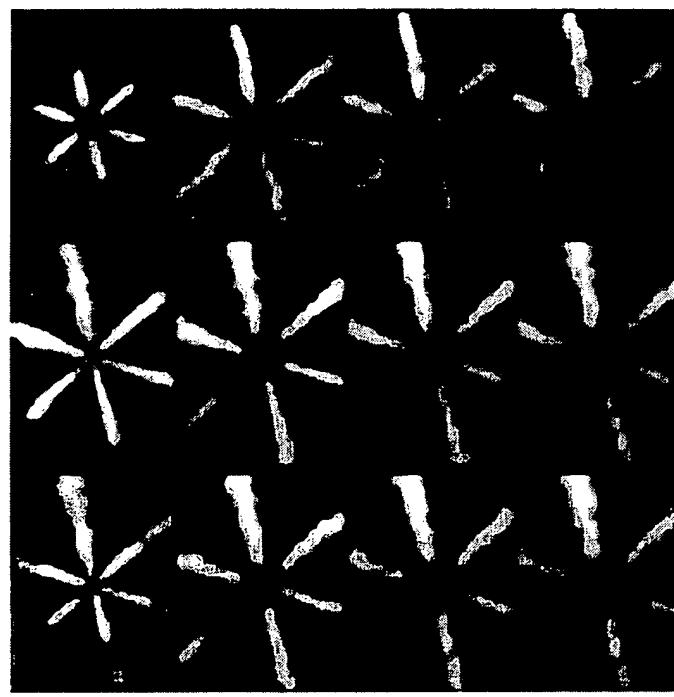


FIG.35

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EXAMPLE OF SPRAY
AT LOW CAMERA SPEED

FIG.36

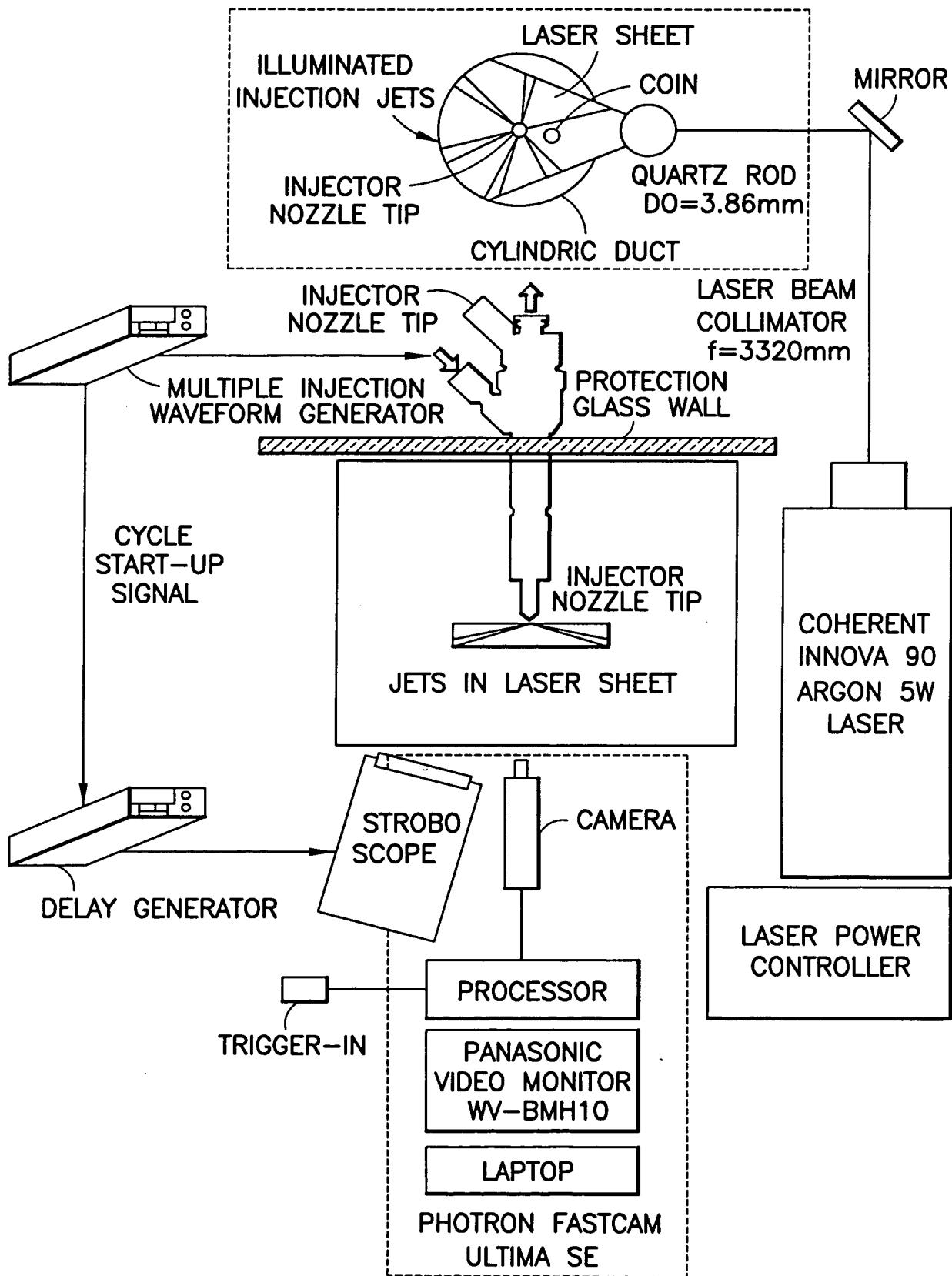
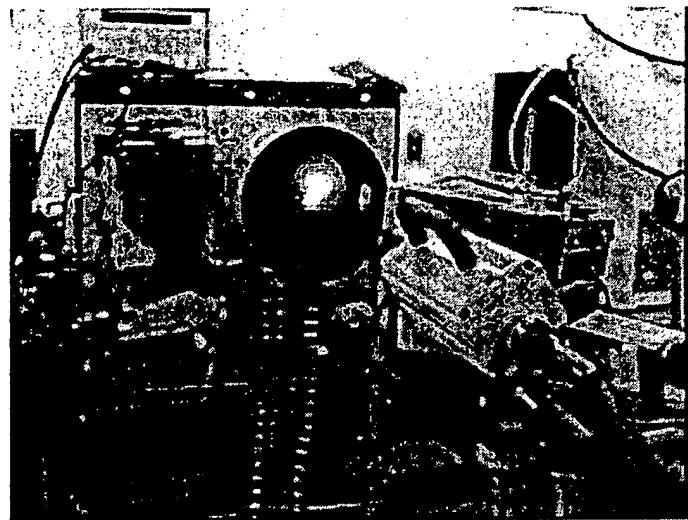
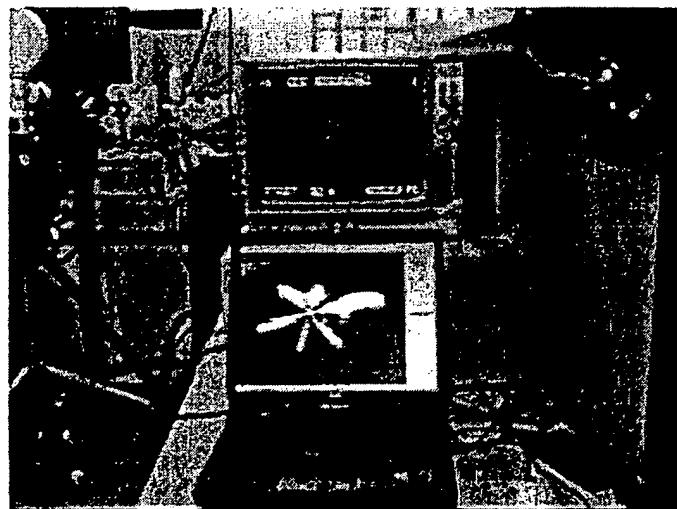


FIG.37

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A. INJECTOR SETUP WITH STROBOSCOPE



B. SIGNAL PROCESSOR WITH MONITOR

FIG.38

VISUALIZATION SPEEDS OF 9,000; 18,000;
27,000 AND 40,500 fps

VISUALIZATION OPTICS SETUP
WHITE DISC IS US QUARTER



t=0126166 s



t=0126222 s



t=0126277 s



t=0126333 s



t=0126388 s

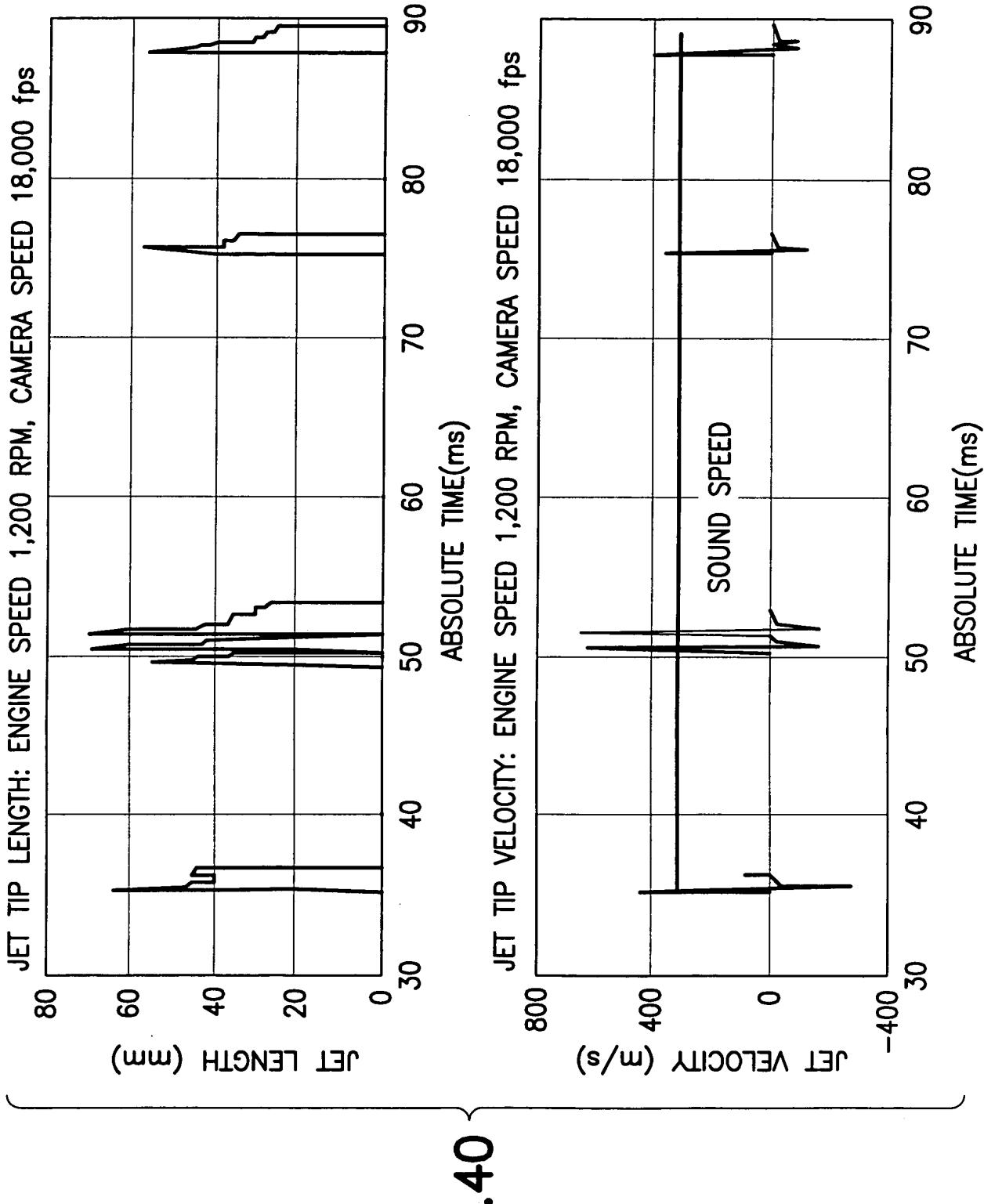
CURRENT TIME
+00:DD:00 126999
FILE INFOR.
FASTCAM - ultimaSE
18000 fps
1 FRAME SEC
256x64
TG START
2719 FRAMES



t=0126333 s

PILOT SHOT IN SIX-SHOT INJECTION: ENGINE SPEED 2,400 RPM,
FRAME DURATION 55.56 μ s, COIN SIZE 24.76 mm.

FIG.39



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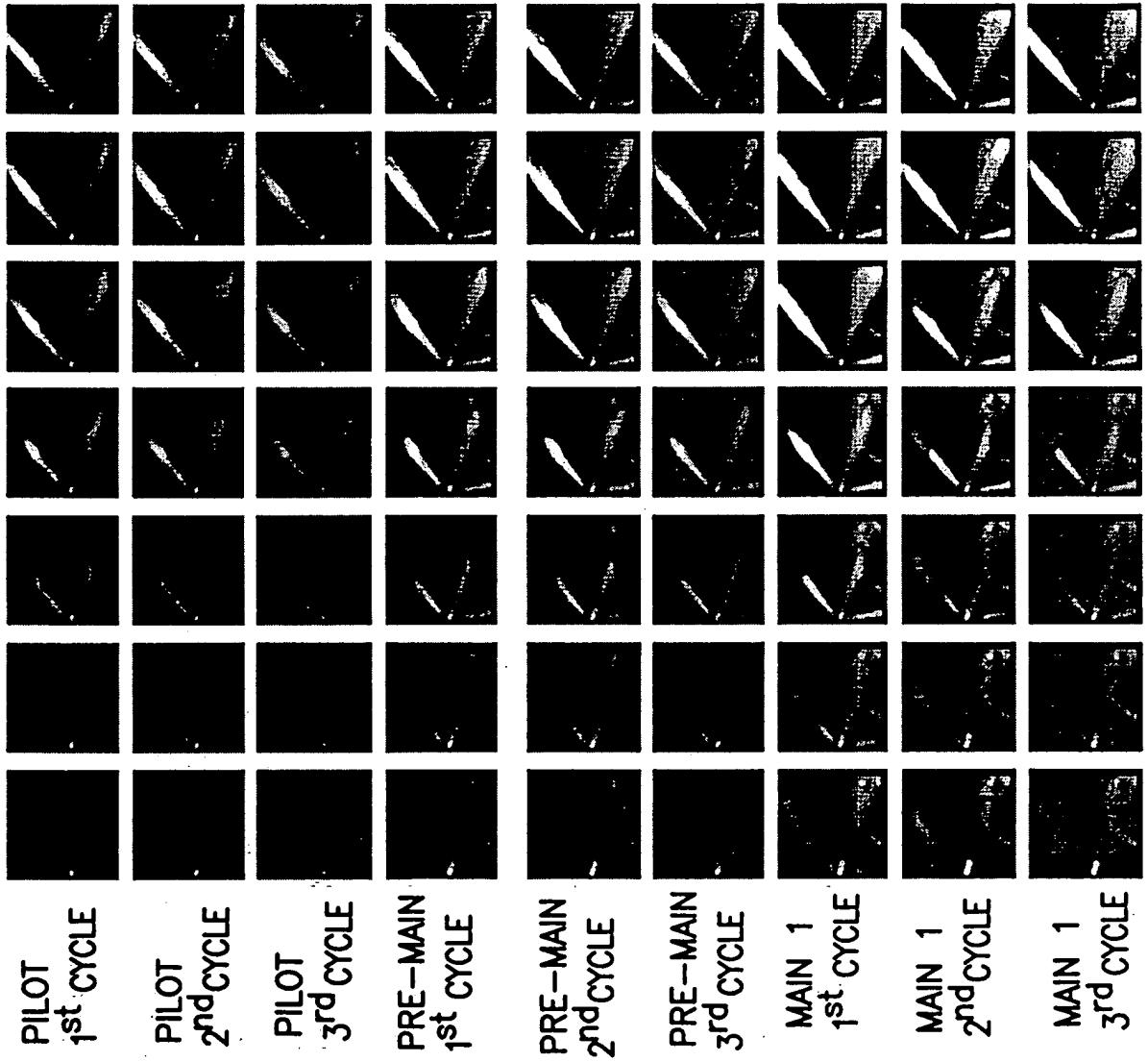


FIG. 41

WAVEFORM ELECTRONIC SETUP, ENGINE SPEED 3,600 RPM						HIGH SPEED CAMERA RECORD AT SPEED OF 40,500 FPS					
DURATION PTS			PHASES PTS MS DEG			DURATION FRAMES			PHASES FRAME MS DEG		
PERIOD	16000	33.3	360	PERIOD	16000	33.3	360	PERIOD	1350	33.333	360
3 Main_dwell_1	288	0.6	6.5	8000	16.667	180	11	0.272	2.9	1969	17.210
2 Pre_M_Pilot	96	0.2	2.2	7712	16.067	173.5	21	0.518	5.6	1940	16.494
1 dwell_2	192	0.4	4.3	5600	11.667	126.0	8	0.198	2.1	1762	12.099
4 Main_2	192	0.4	4.3	8528	17.767	191.9	28	0.198	2.1	178.1	130.7
5 After_M	240	0.5	5.4	12000	25.000	270.0	14	0.691	7.5	2008	18.173
6 Post	192	0.4	4.3	14000	29.167	315.0	9	0.346	3.7	2302	196.3
							7	0.222	2.4	2472	25.432
								0.173	1.9	29.630	274.7
											320.0
Pilot-to-Pre_M	1920	4.000	43.2	Pilot-to-Pre_M	1920	4.000	43.2	Pilot-to-Pre_M	170	4.198	45
Pre_M-to-Main1	96	0.200	2.16	Pre_M-to-Main1	96	0.200	2.16	Pre_M-to-Main1	21	0.519	6
Main1-to-Main2	240	0.500	5	Main1-to-Main2	240	0.500	5	Main1-to-Main2	28	0.691	7
Main2-to-AfterM	3232	6.733	73	Main2-to-AfterM	3232	6.733	73	Main2-to-AfterM	280	6.914	75
AfterM-to-Post	1808	3.767	41	AfterM-to-Post	1808	3.767	41	AfterM-to-Post	161	3.975	43

FIG.42

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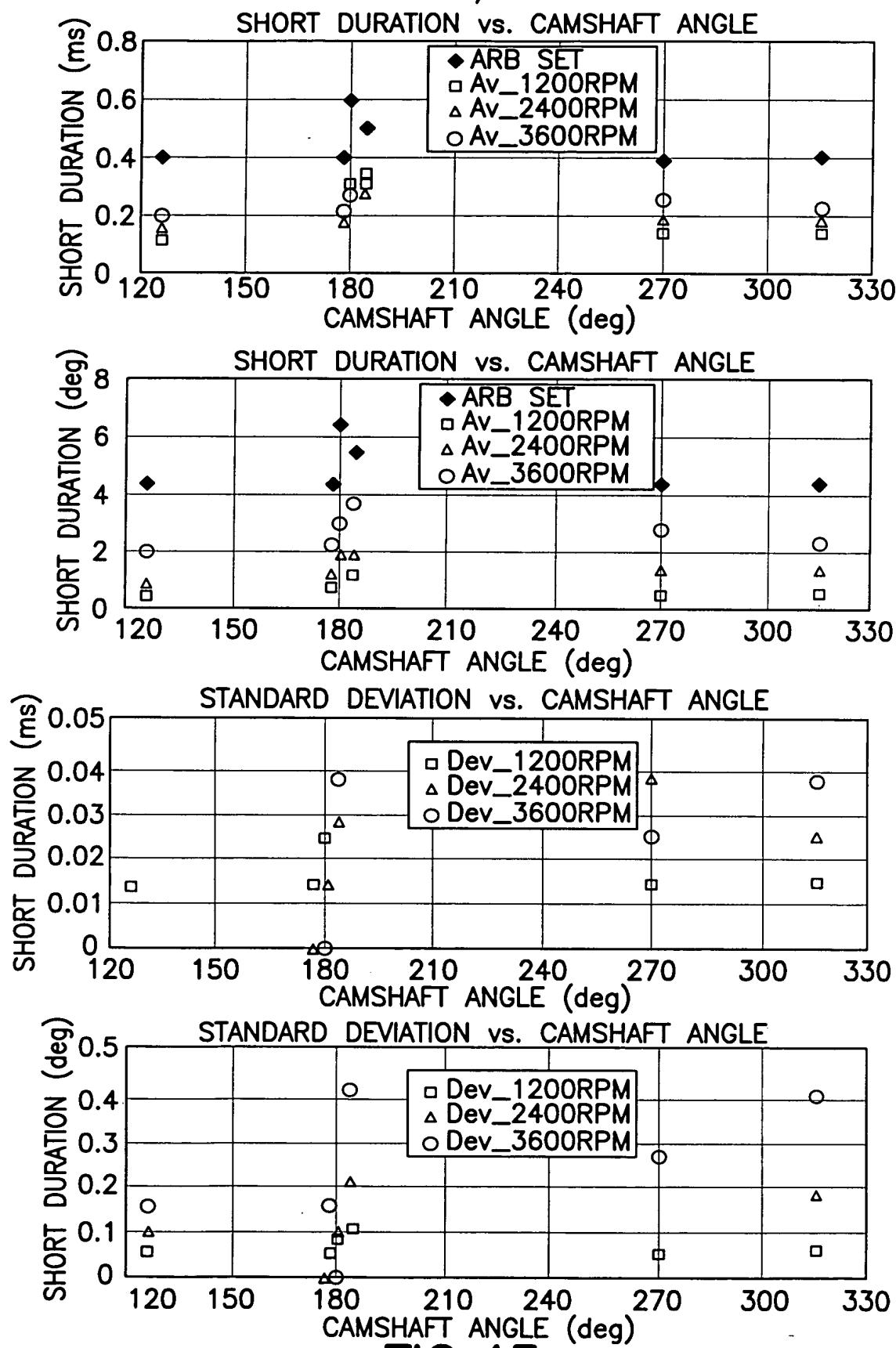


FIG.43

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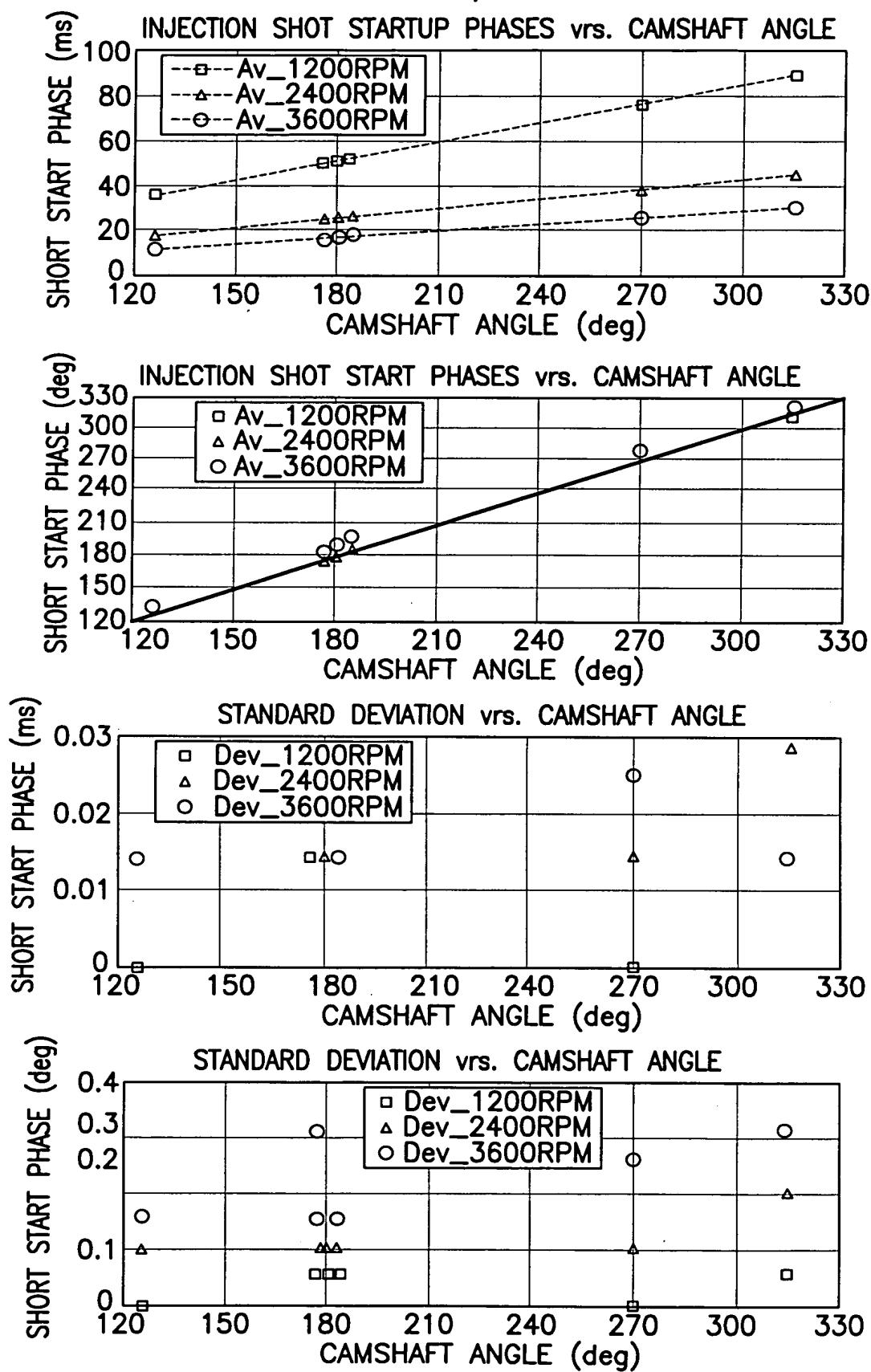


FIG.44

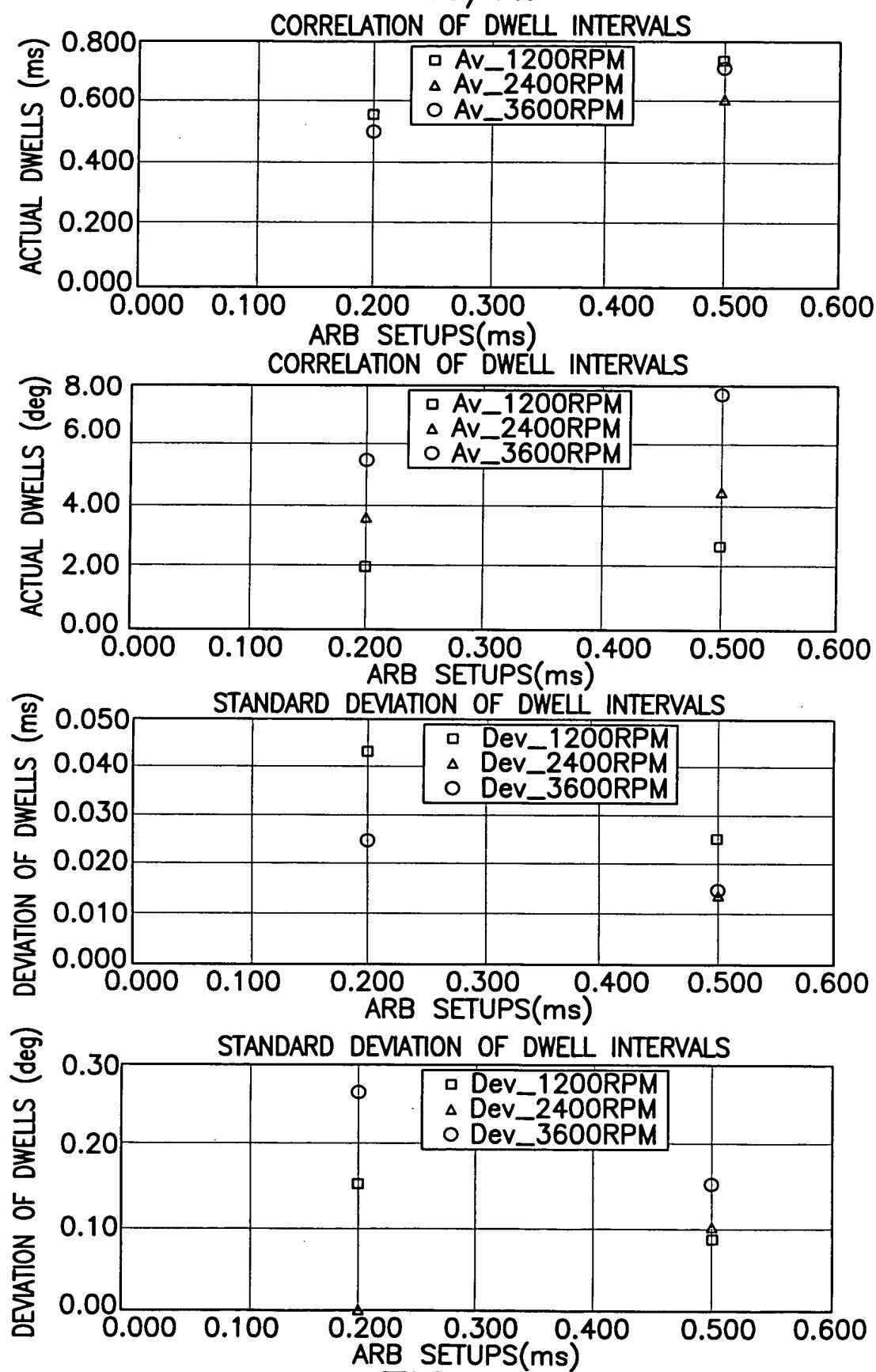


FIG.45

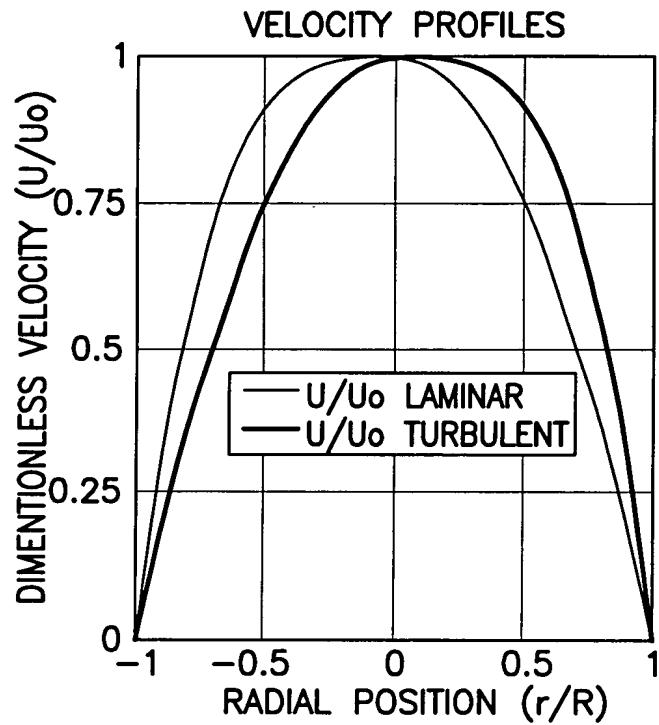


FIG.46

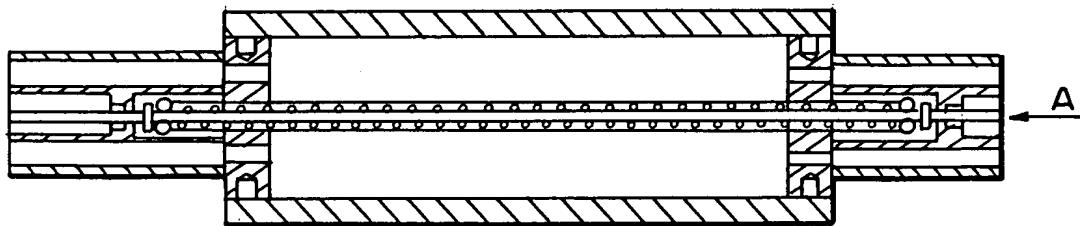


FIG.48

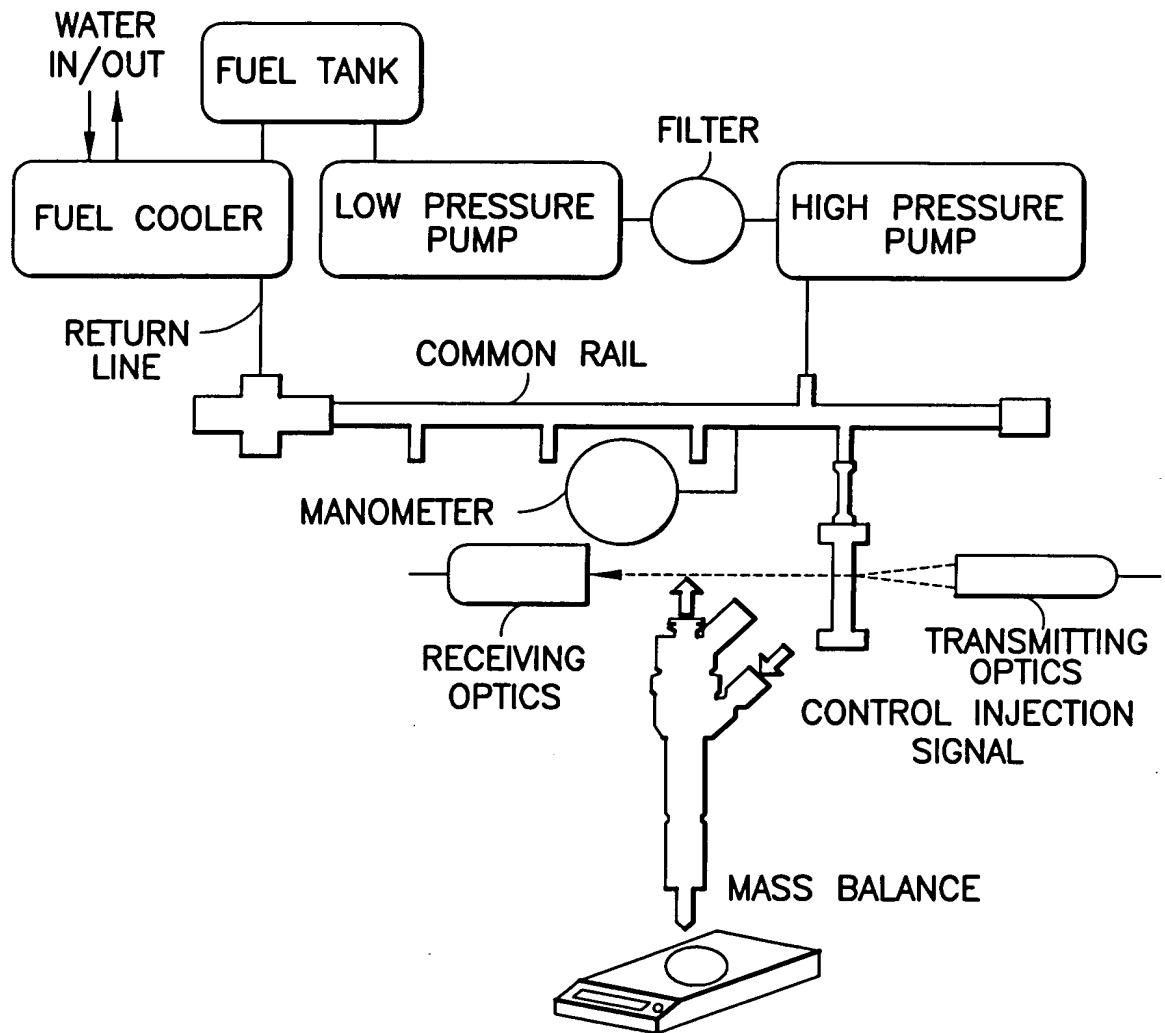


FIG.47

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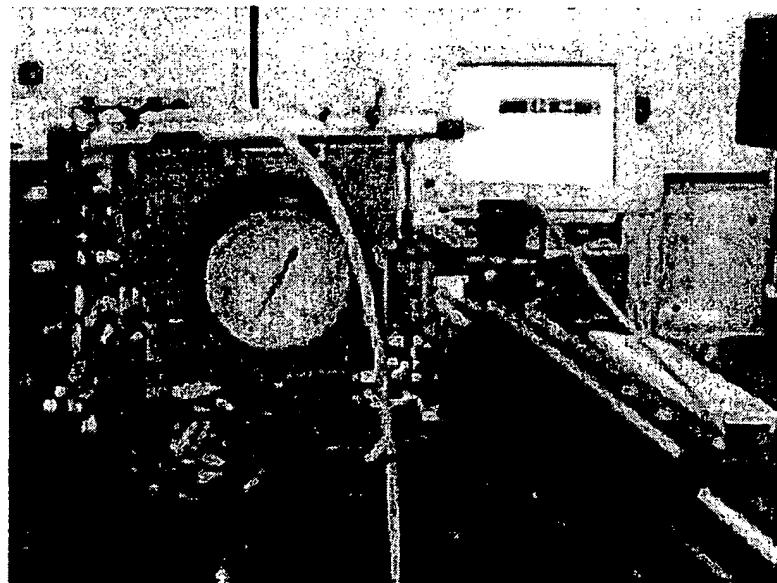


FIG.49

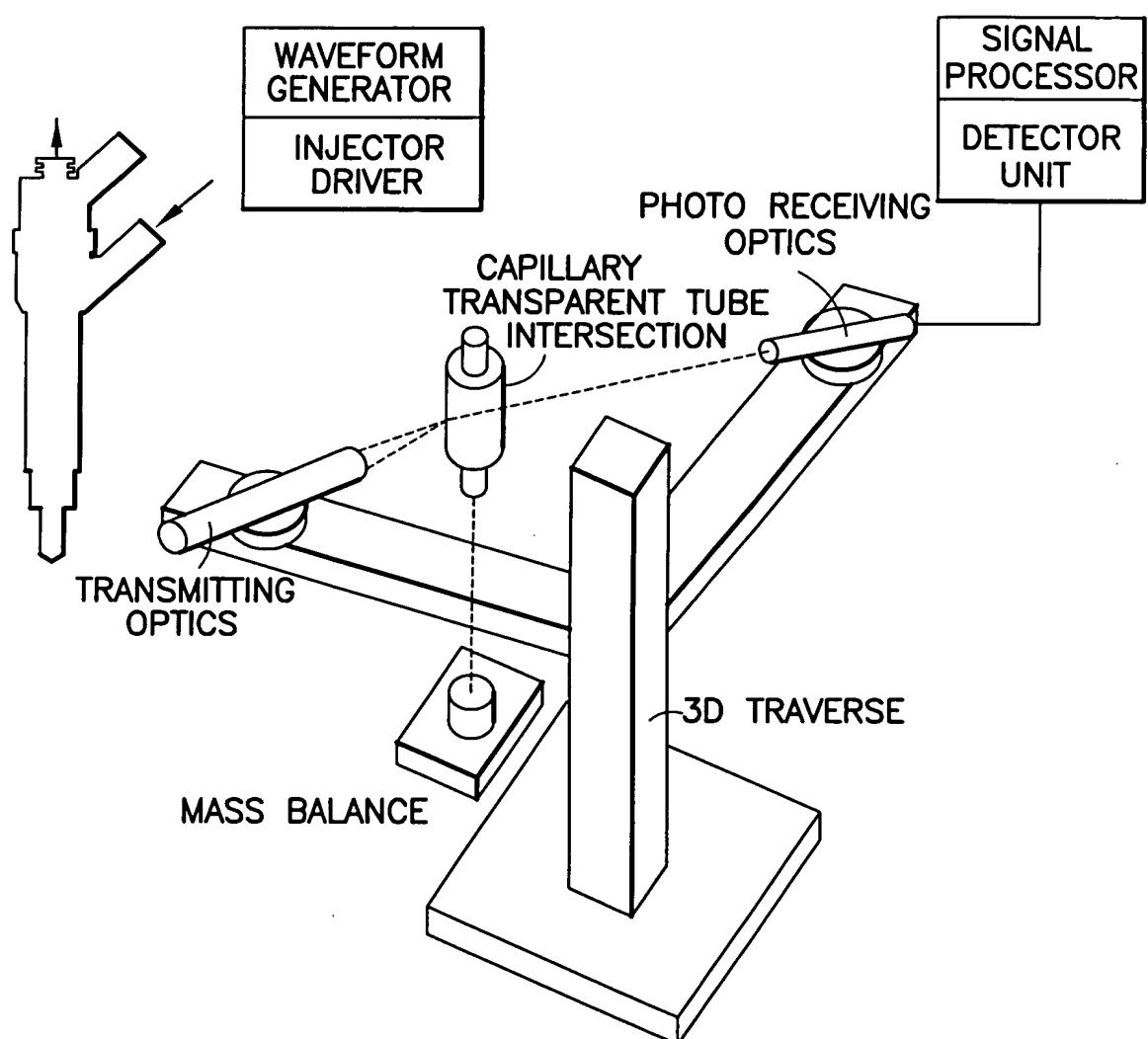


FIG.50

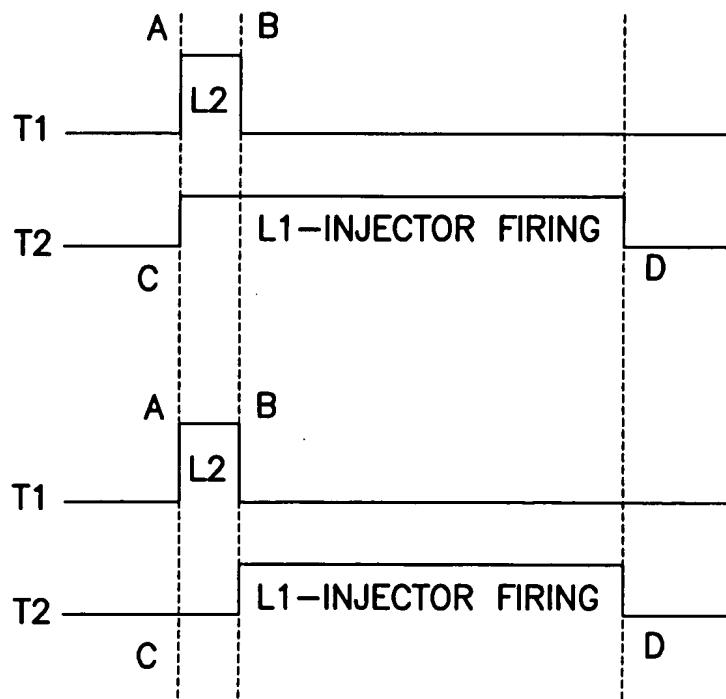
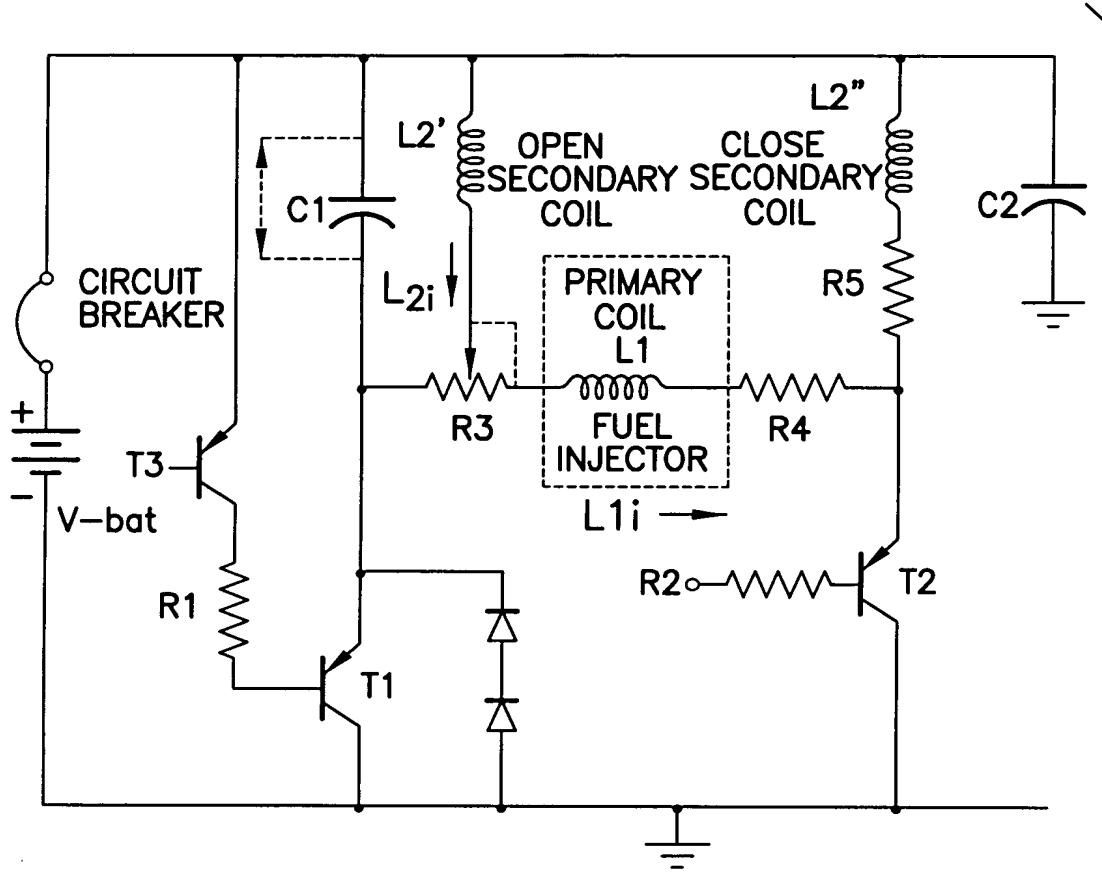
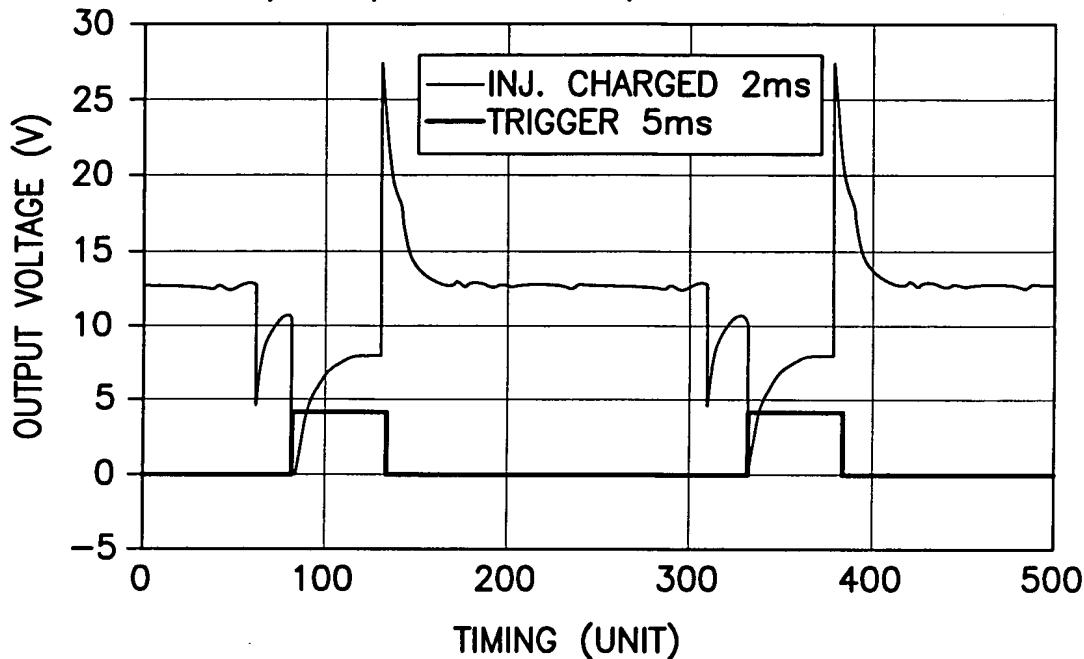


FIG.51

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SIMULTANEOUSLY CHARGED SECONDARY COIL: $f=40\text{Hz}$
 $A=T$, $B=C$, $C=A+\text{CHARGE}$, $D=C+\text{INJ. DURATION}$



PRECHARGED SECONDARY COIL: $f=40\text{Hz}$
 $A=T$, $B=A+\text{CHARGE TIME}$, $C=A$, $D=C+\text{INJ. DURATION}$

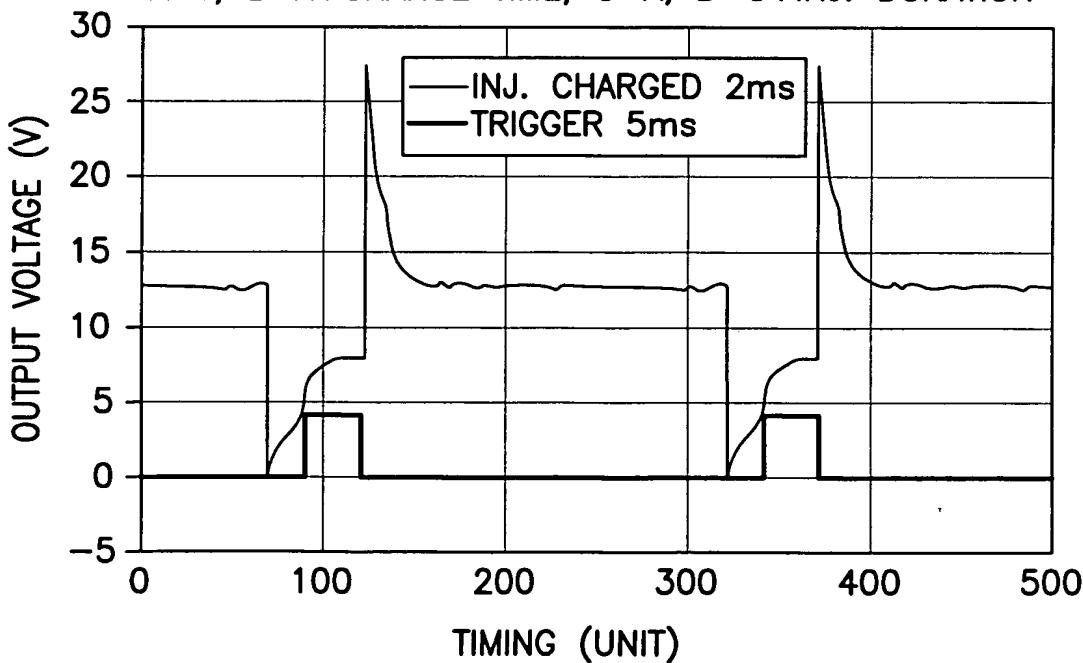
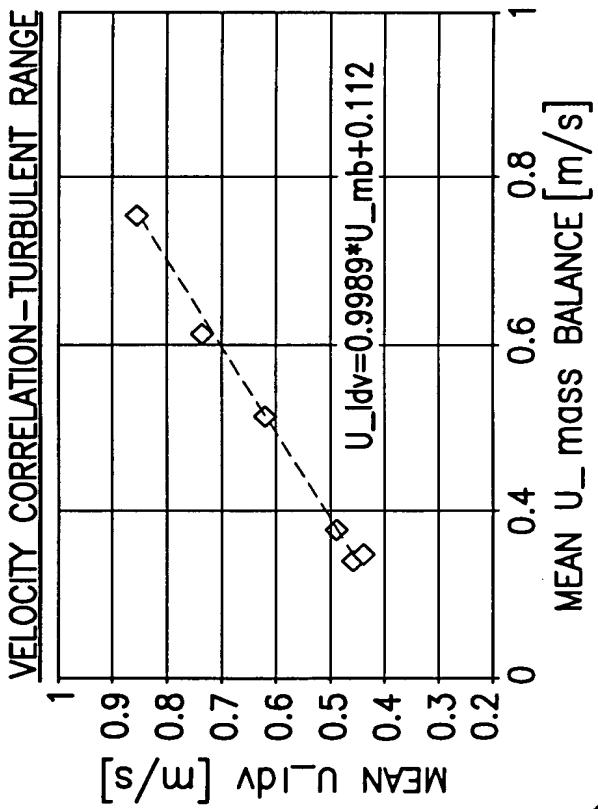
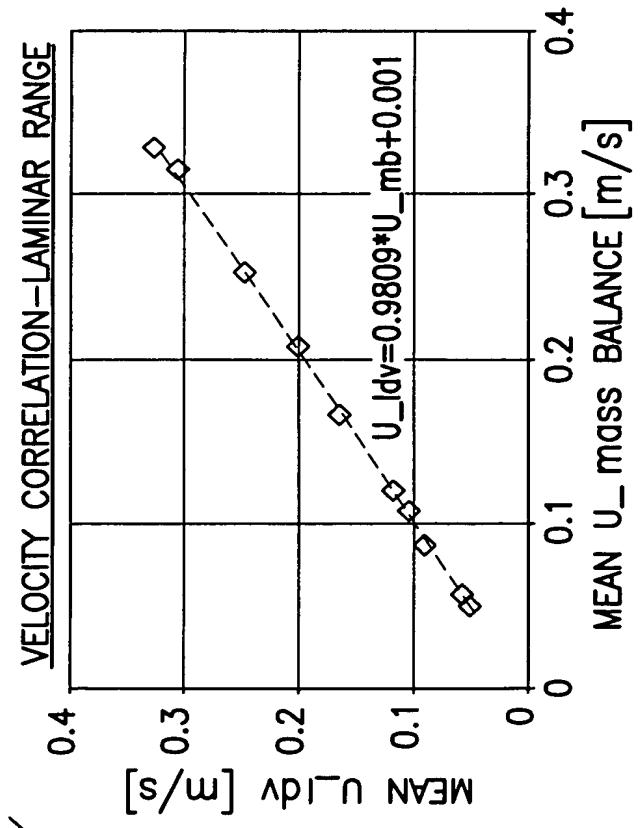
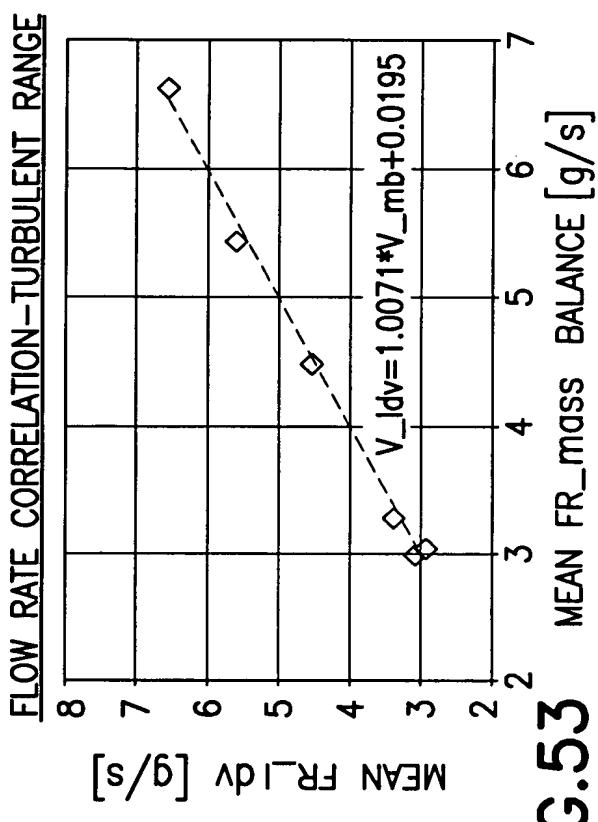
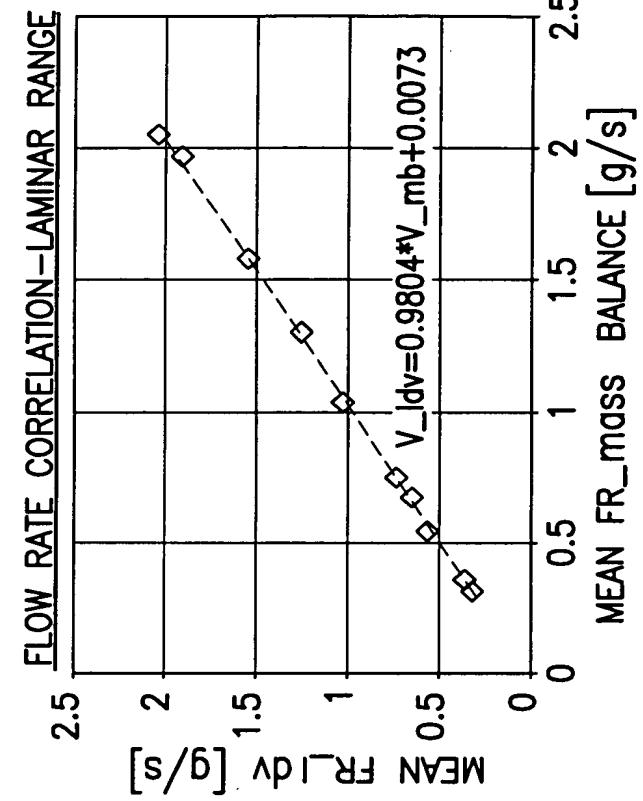


FIG.52

**FIG.53**

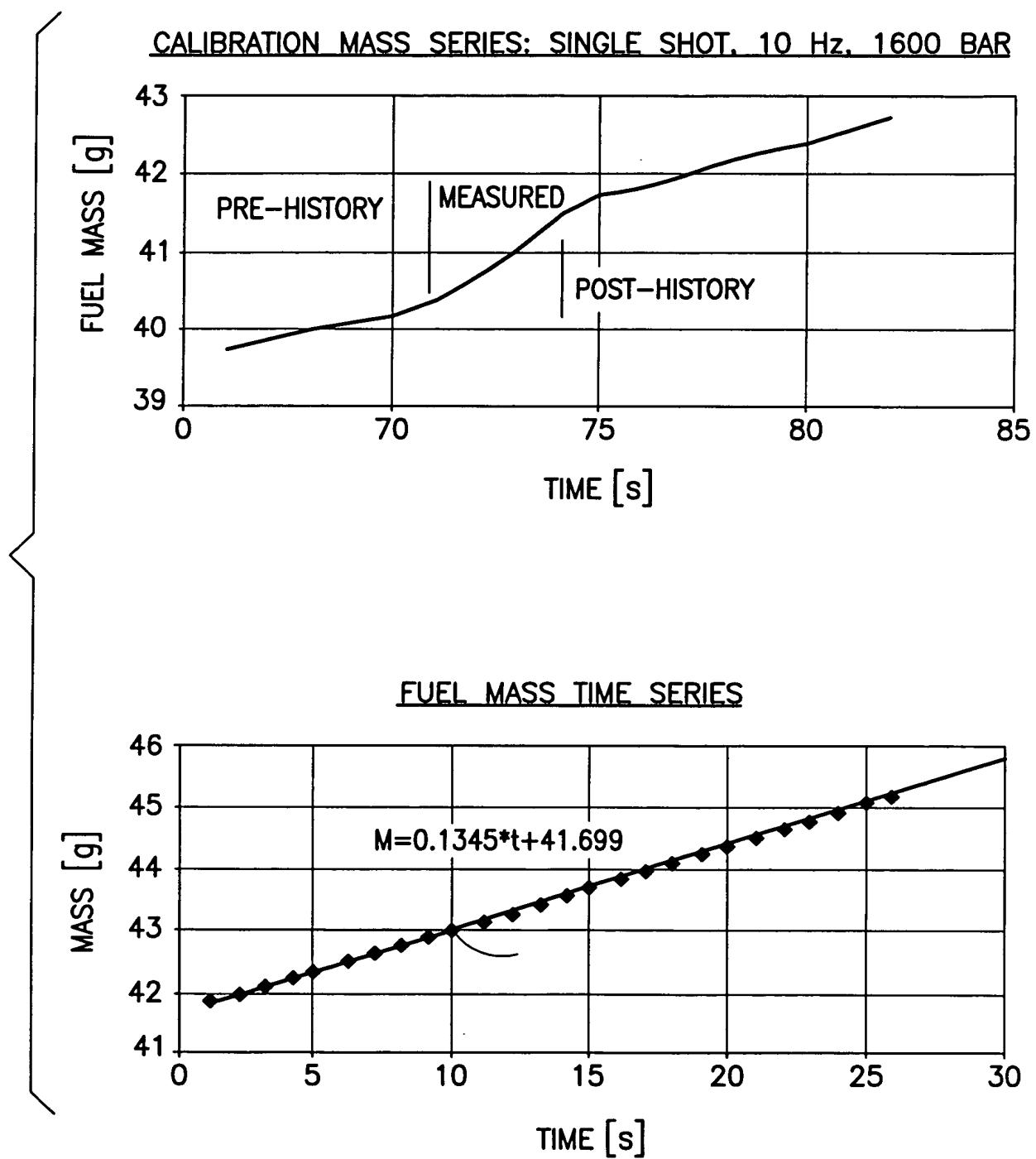


FIG.54

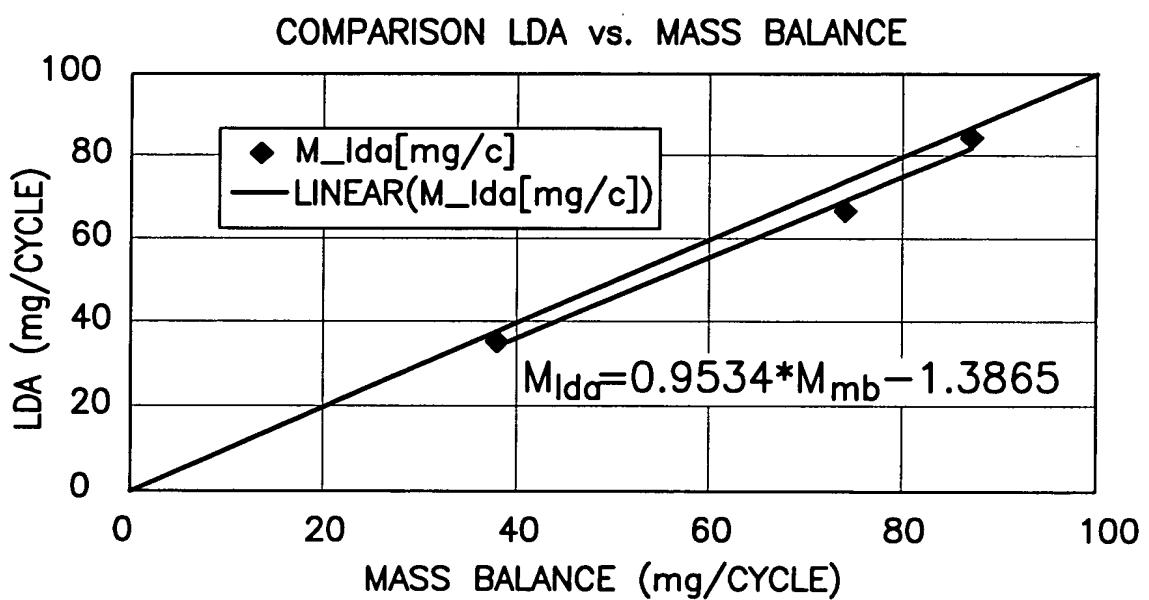


FIG.55

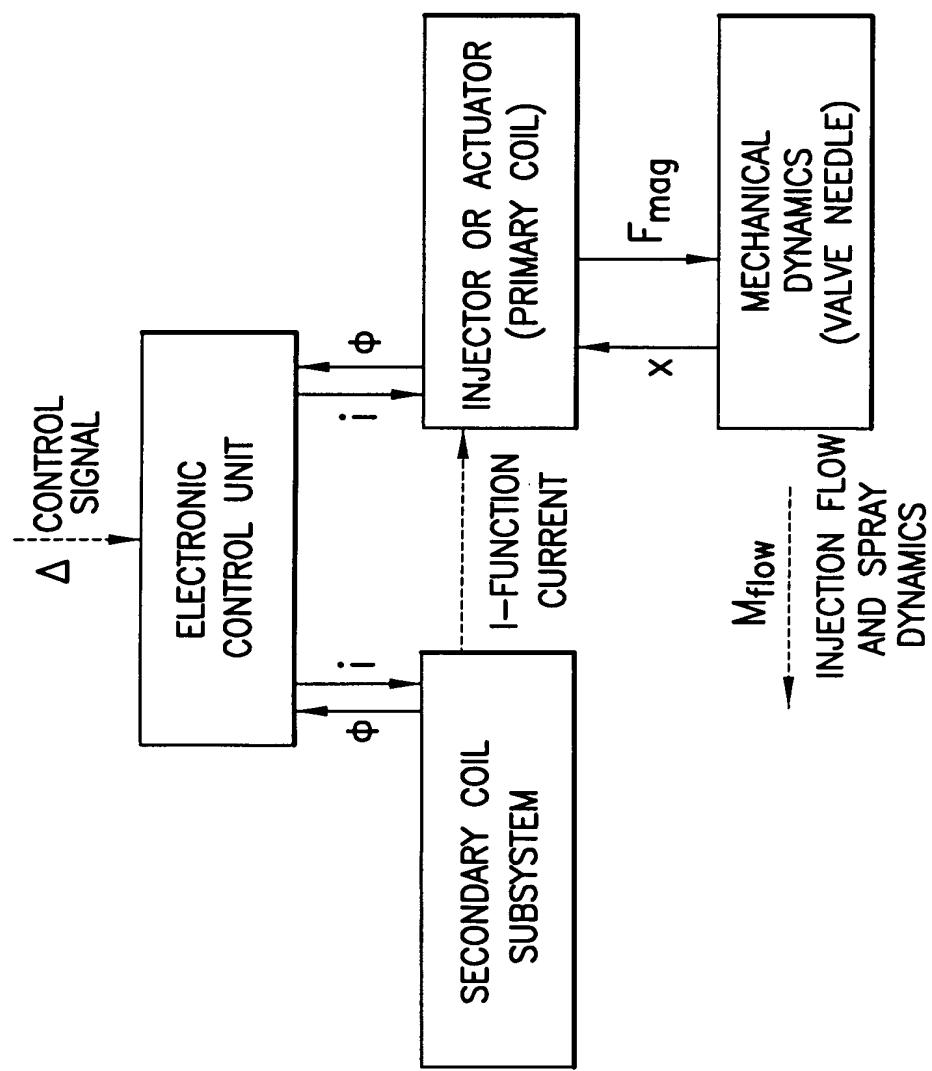
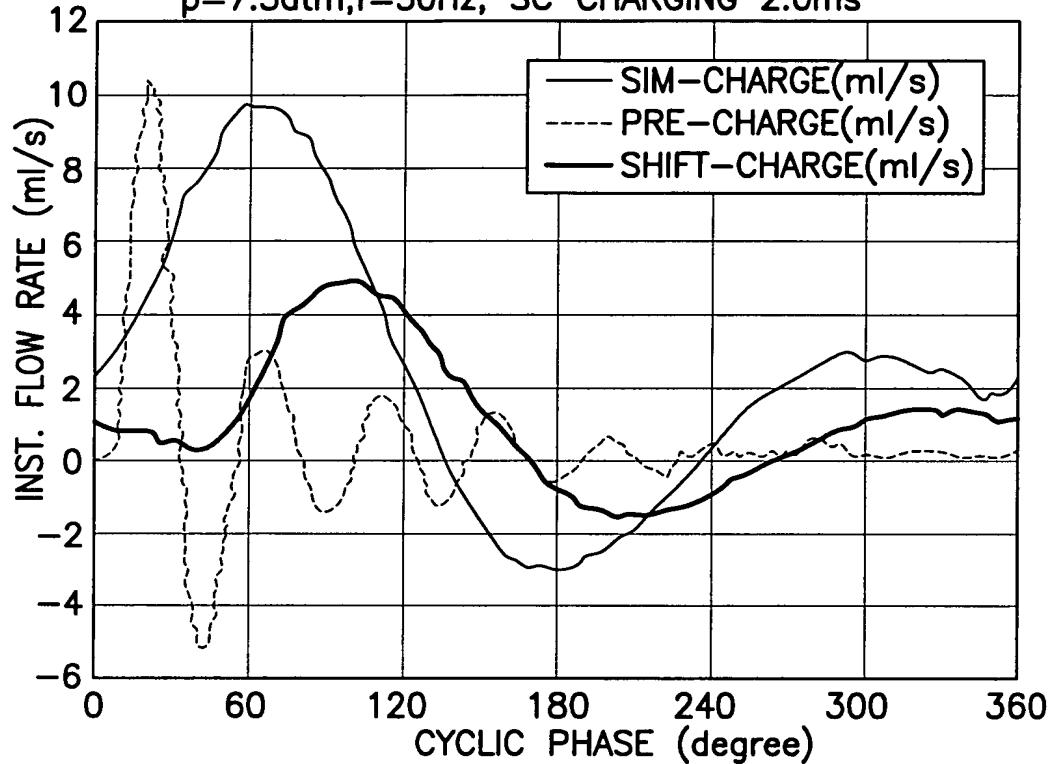


FIG.56

COMPARISON OF DIFFERENT CHARGING SCENARIOS:
 $p=7.3\text{atm}$, $f=50\text{Hz}$, SC CHARGING 2.0ms



COMPARISON OF DIFFERENT SC CHARGING SCENARIOS:
 $p=7.3\text{atm}$, $f=50\text{Hz}$, SC CHARGING 2.0ms, $\tau=3\&5\text{ms}$

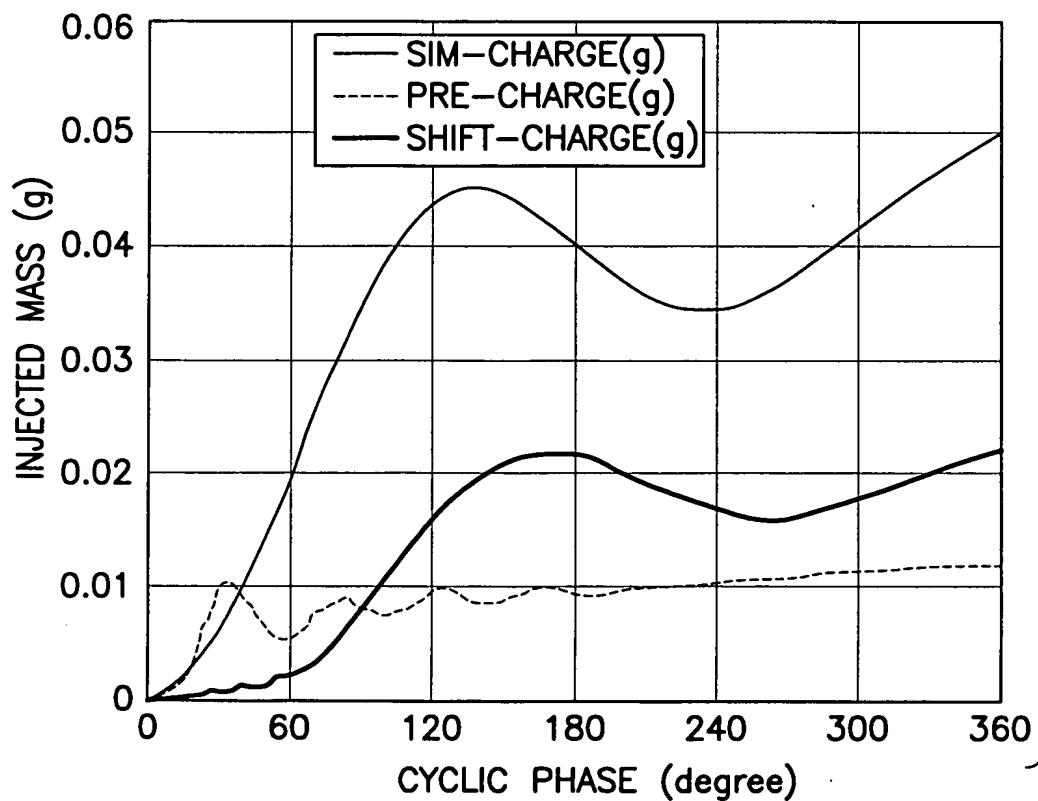
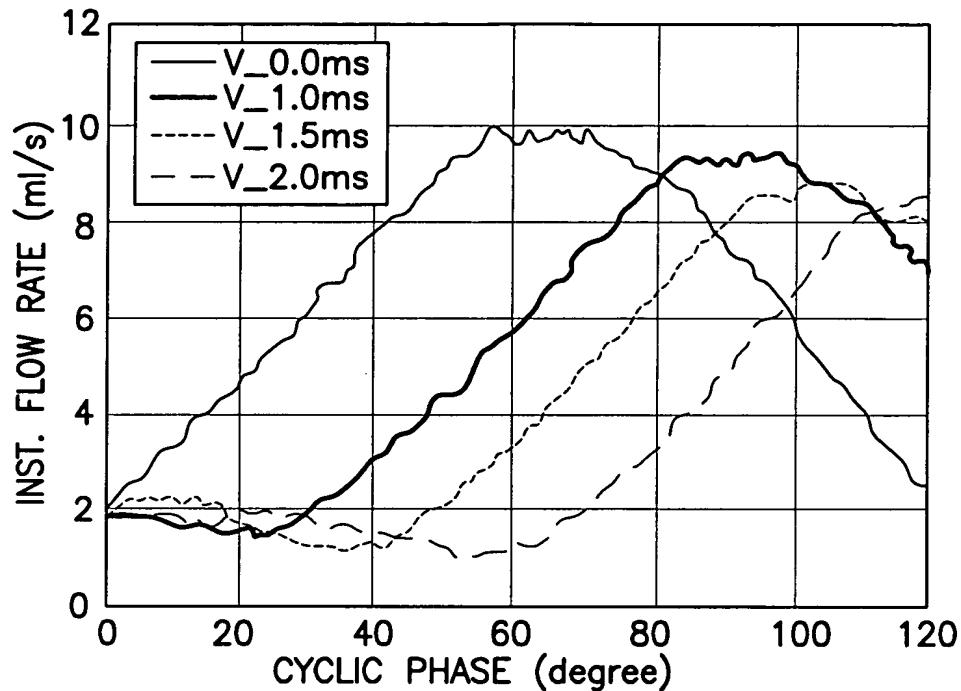


FIG.57

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SIMULTANEOUSLY CHARGED SC: CHARGING 0.0, 1.0,
1.5 AND 2.0ms; f=50Hz, tau=5ms, p=7.3atm



SIMULTANEOUSLY CHARGED SC: CHARGING 0.0, 1.0,
1.5 AND 2.0ms; f=50Hz, tau=5ms, p=7.3atm

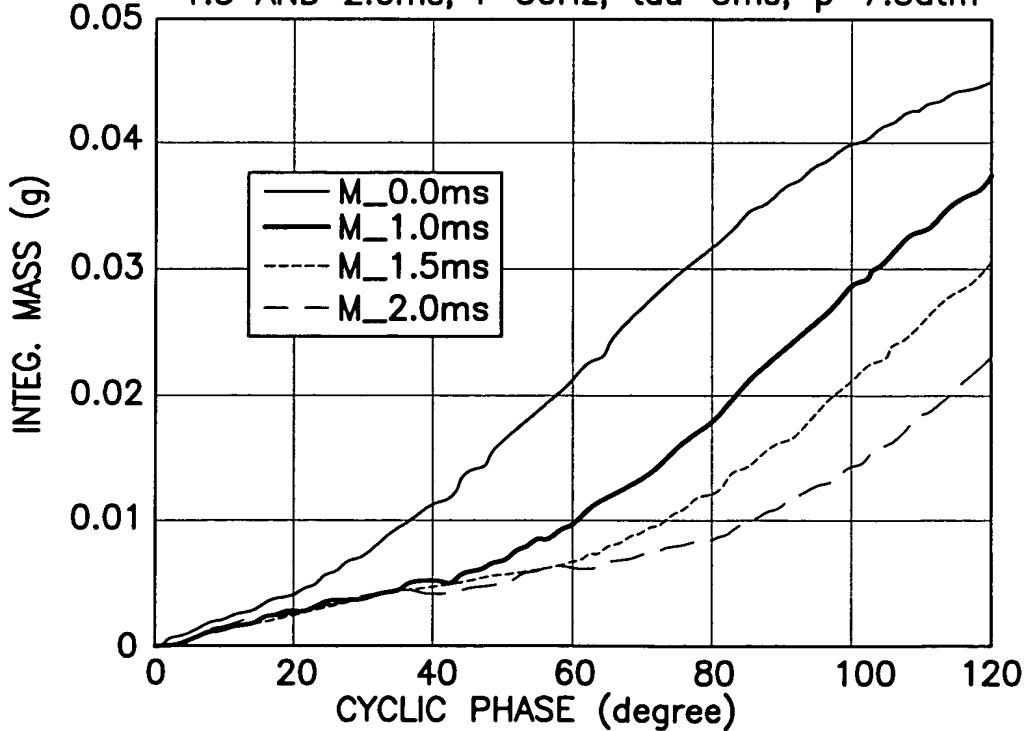


FIG.58A

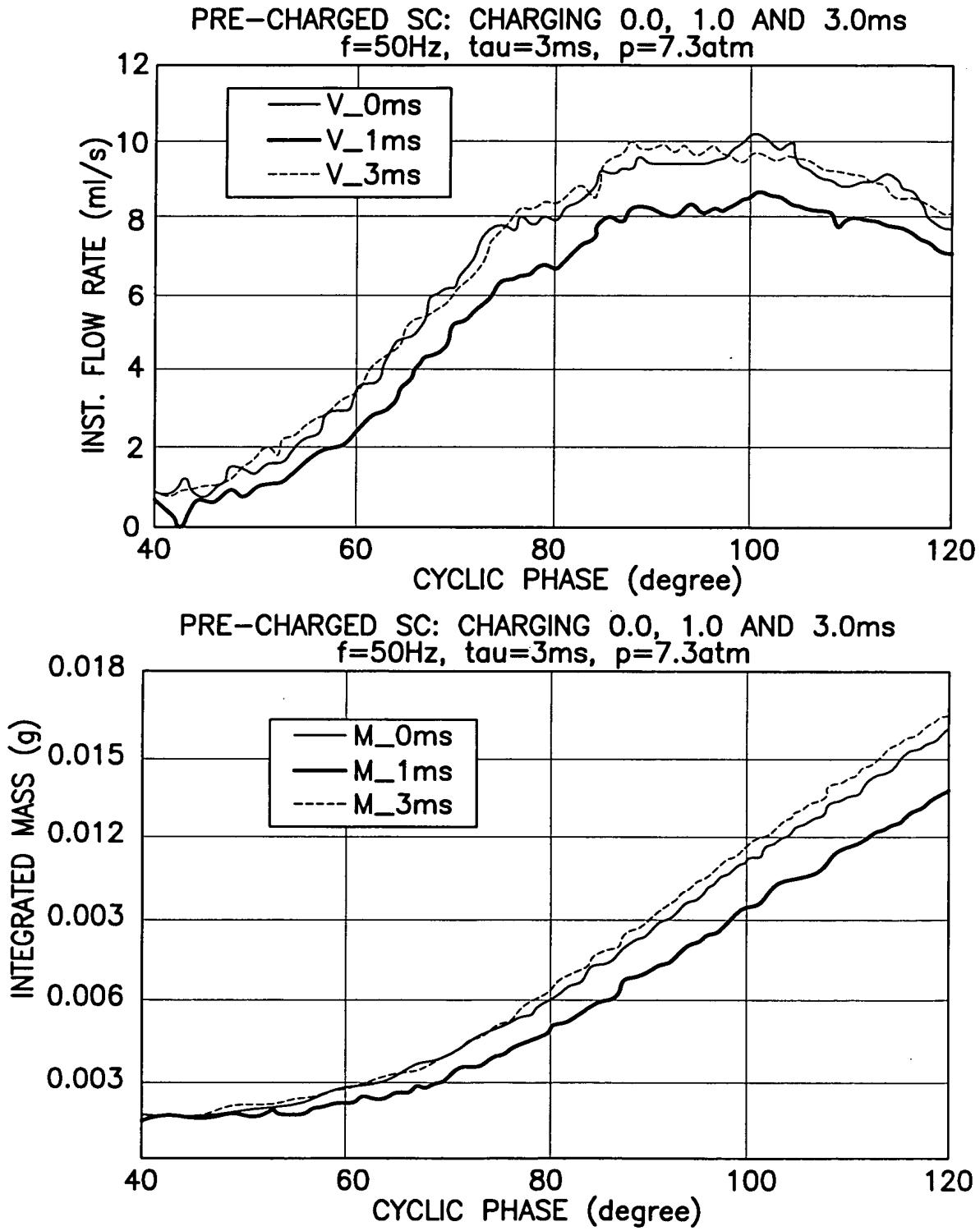
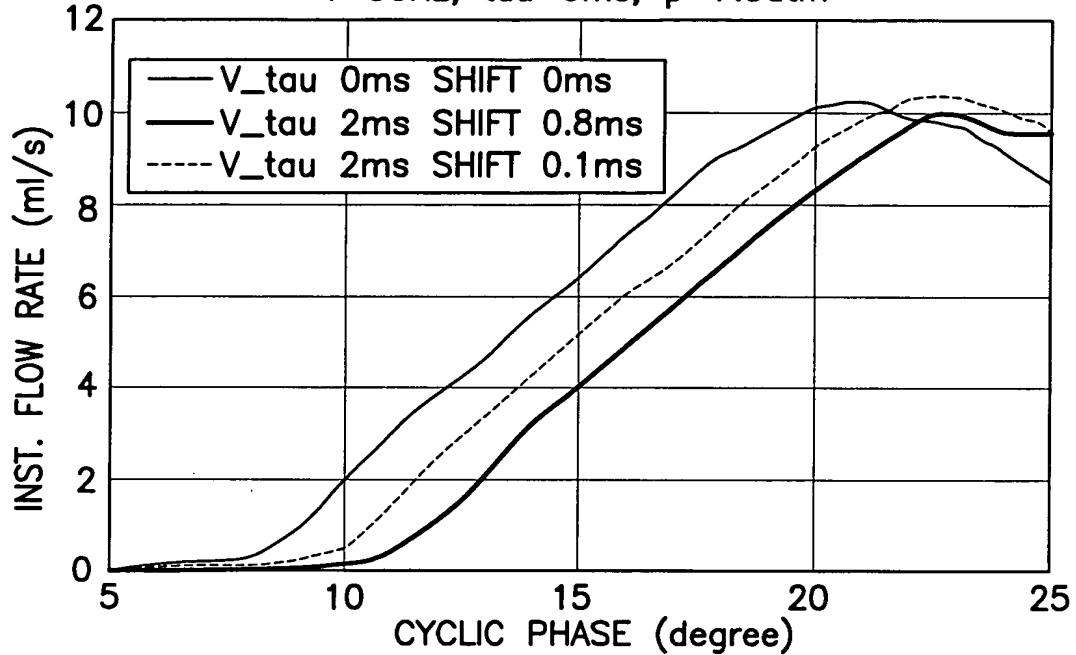


FIG.58B

SHIFTED CHARGE: CHARGING 0 AND 2 ms;
 $f=50\text{Hz}$, $\tau=5\text{ms}$, $p=7.3\text{atm}$



SHIFTED CHARGE: CHARGING 0 AND 2 ms;
 $f=50\text{Hz}$, $\tau=0$ AND 2ms , $p=7.3\text{atm}$

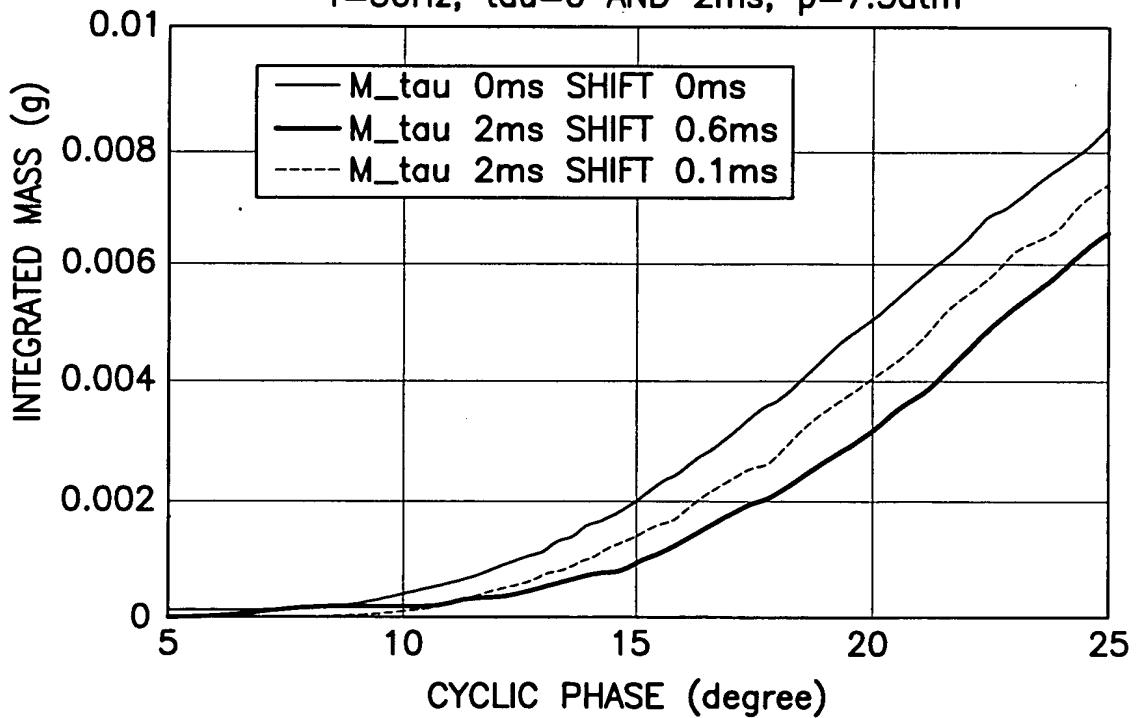
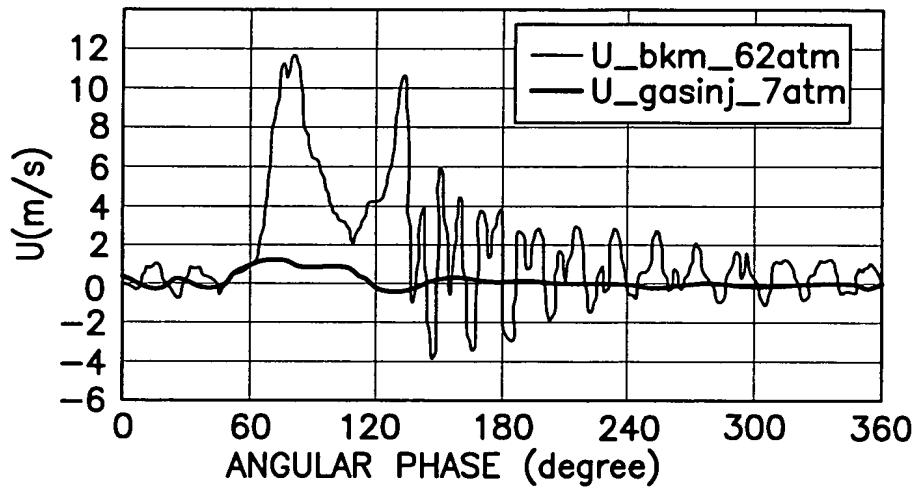


FIG.58C

CENTERLINE VELOCITY TIME SERIES UNDER SERVO-JET (bkm) AND GASOLINE INJECTION



VOLUMETRIC FLOW RATE TIME SERIES UNDER DIESEL AND GASOLINE INJECTION PRESSURE

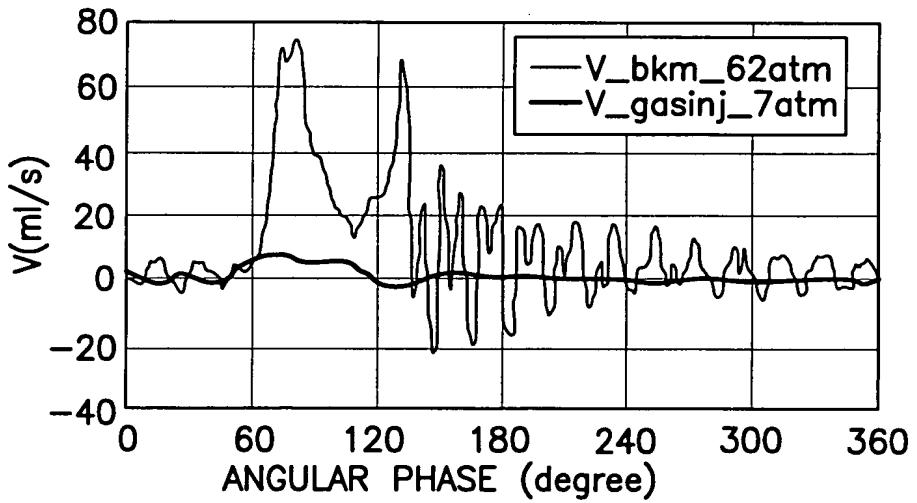


FIG.59

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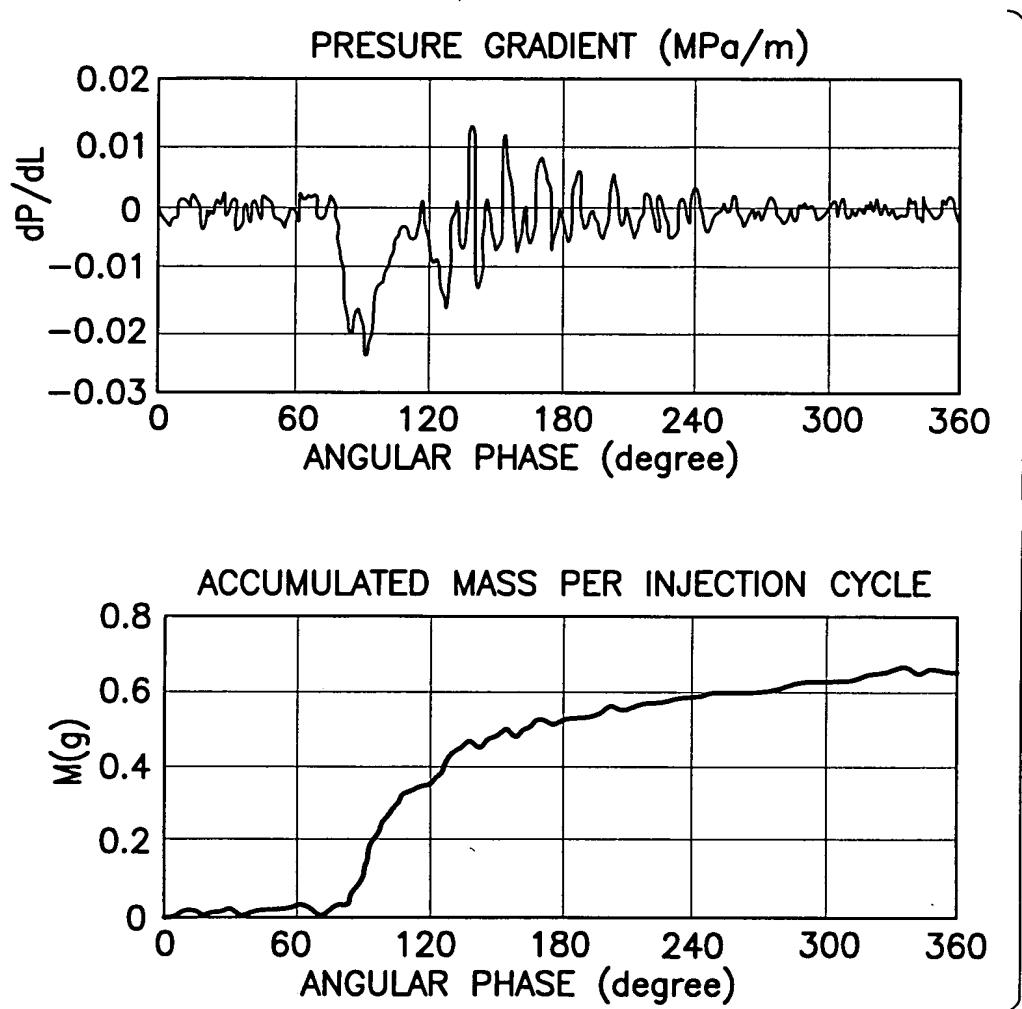
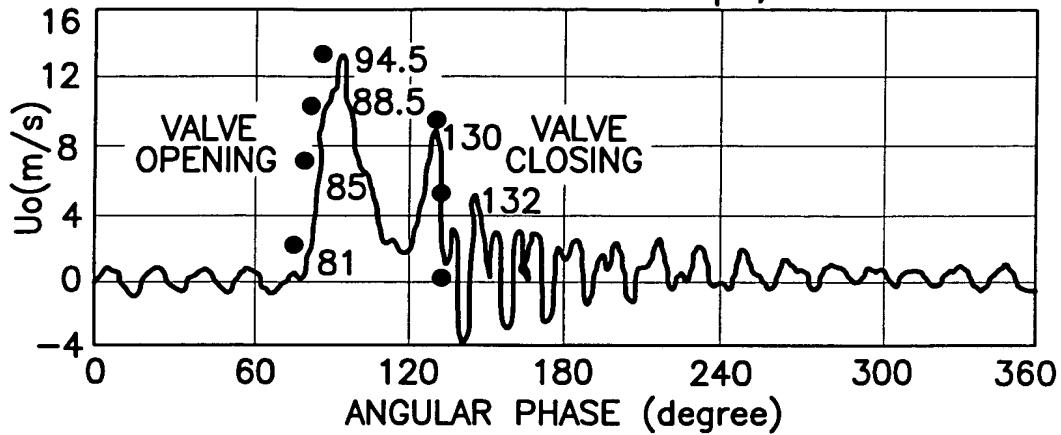


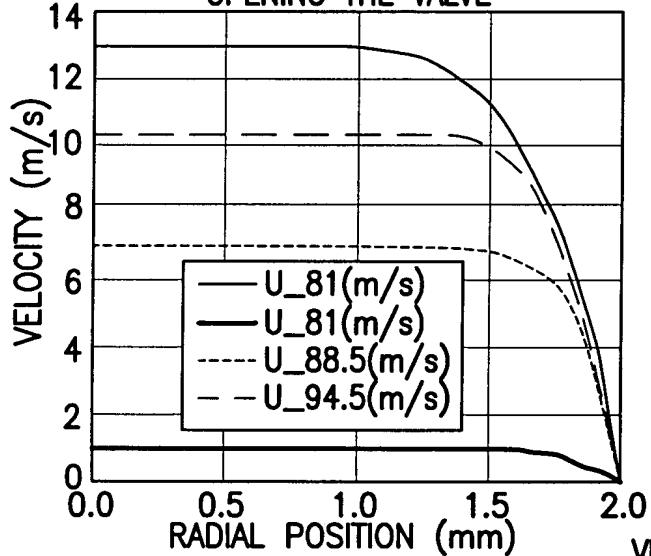
FIG.60

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CENTERLINE VELOCITY: RAIL PRESSURE 800pst, CYCLING 822 RPM



VELOCITY PROFILE AT DIFFERENT PHASES:
OPENING THE VALVE



VELOCITY PROFILE AT DIFFERENT PHASES:
CLOSING THE VALVE

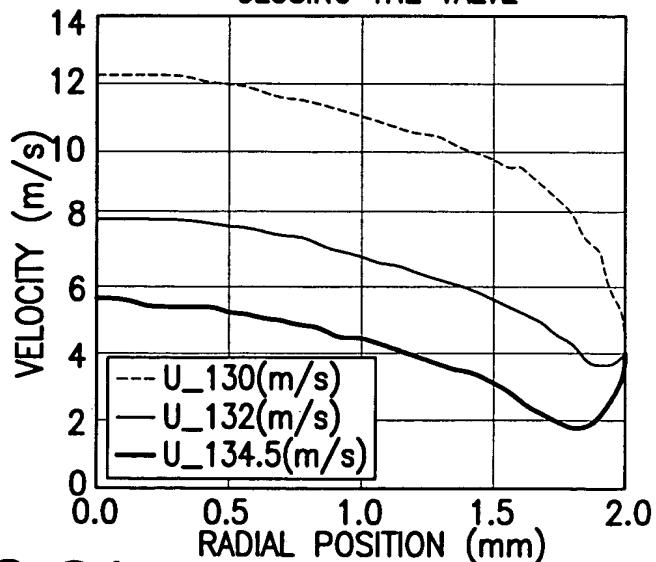
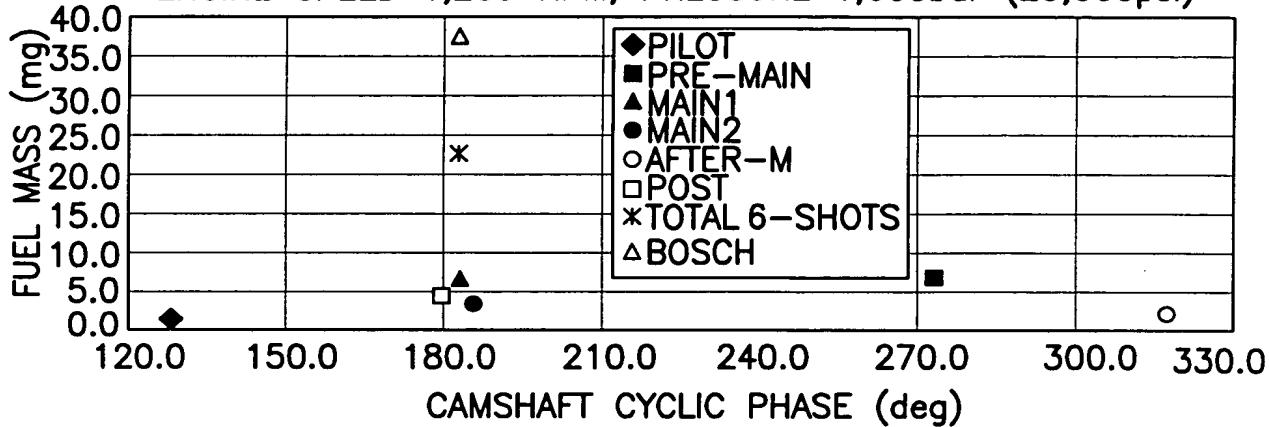


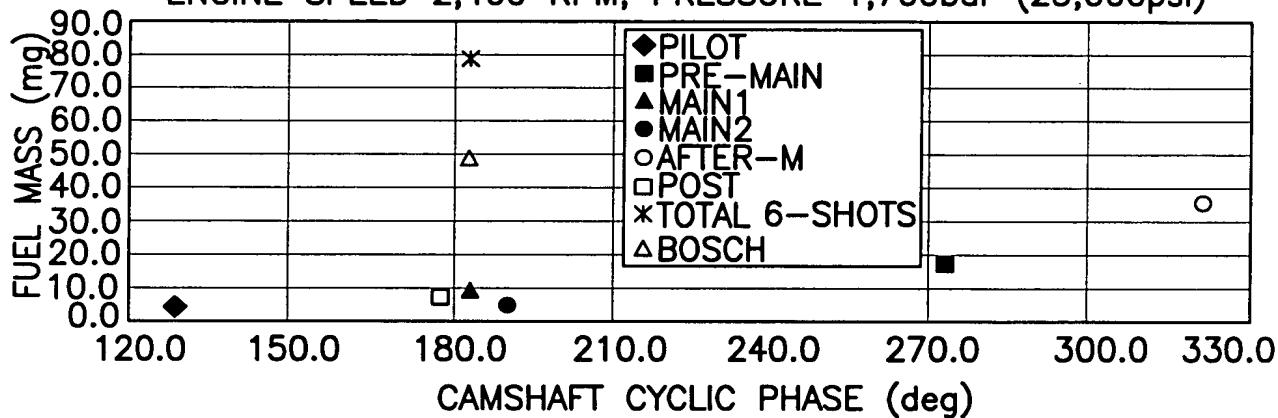
FIG.61

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FUEL MASS INJECTION PER CYCLE:
ENGINE SPEED 1,200 RPM, PRESSURE 1,600bar (23,000psi)



FUEL MASS INJECTION PER CYCLE:
ENGINE SPEED 2,400 RPM, PRESSURE 1,700bar (25,000psi)



FUEL MASS INJECTION PER CYCLE:
ENGINE SPEED 3,600 RPM, PRESSURE 1,700bar (25,000psi)

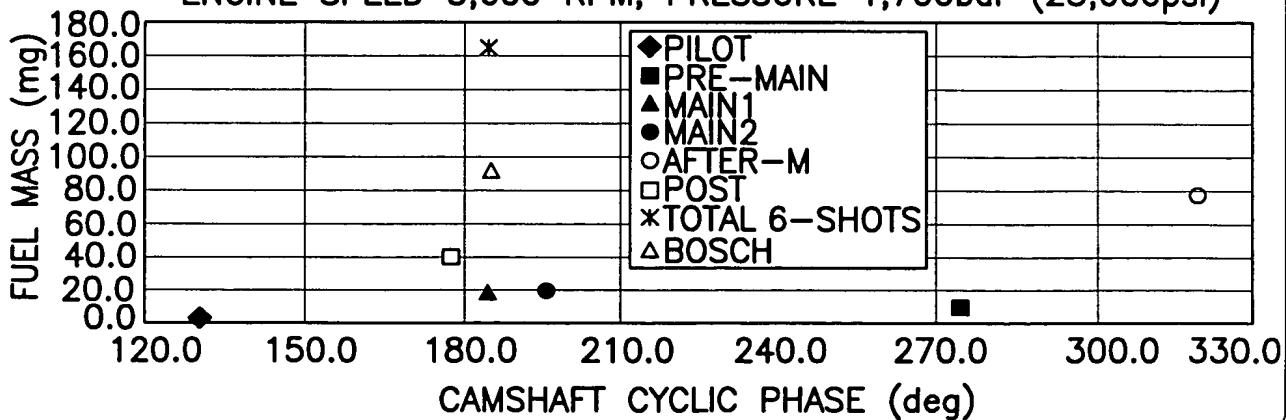


FIG.62

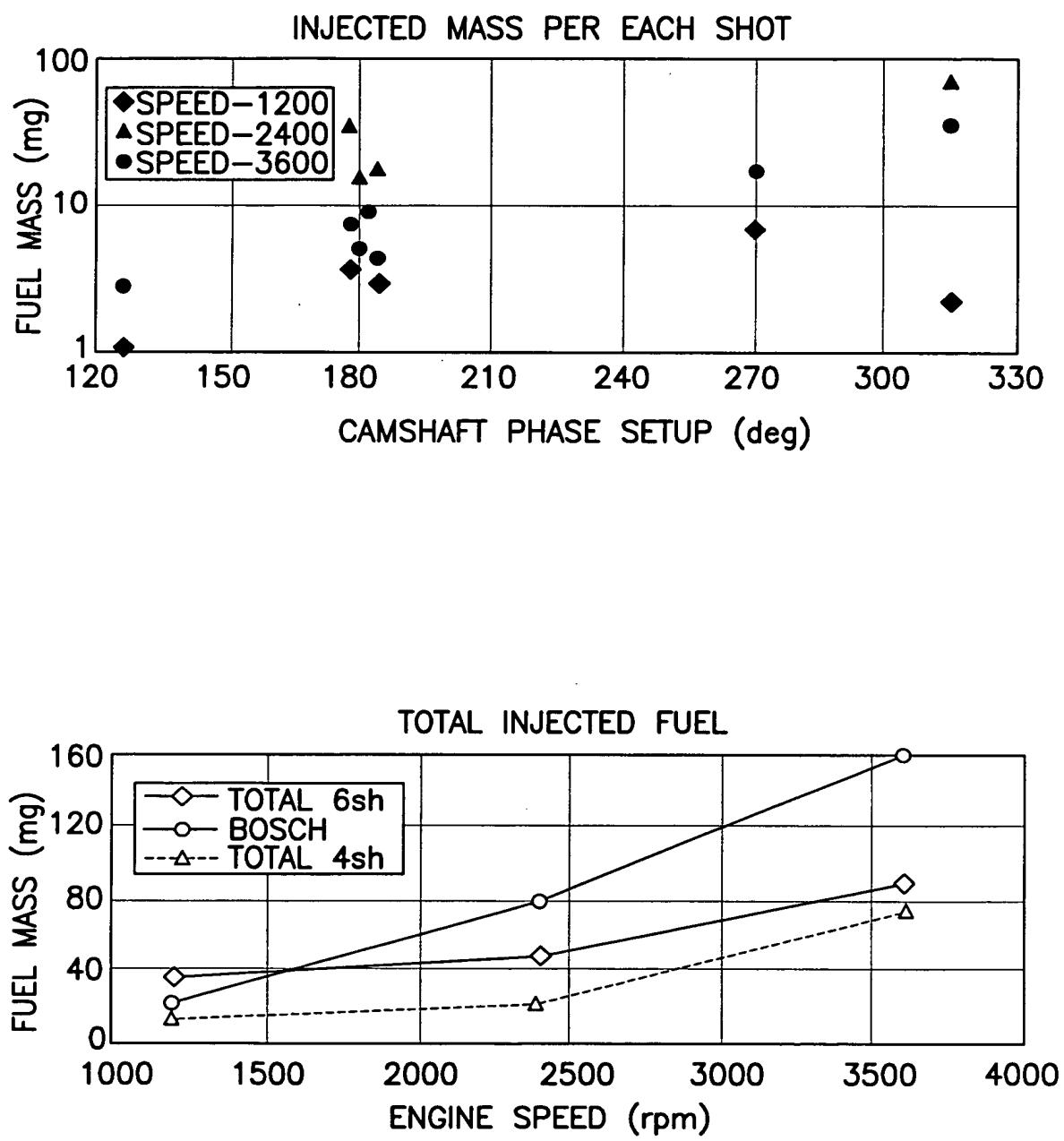
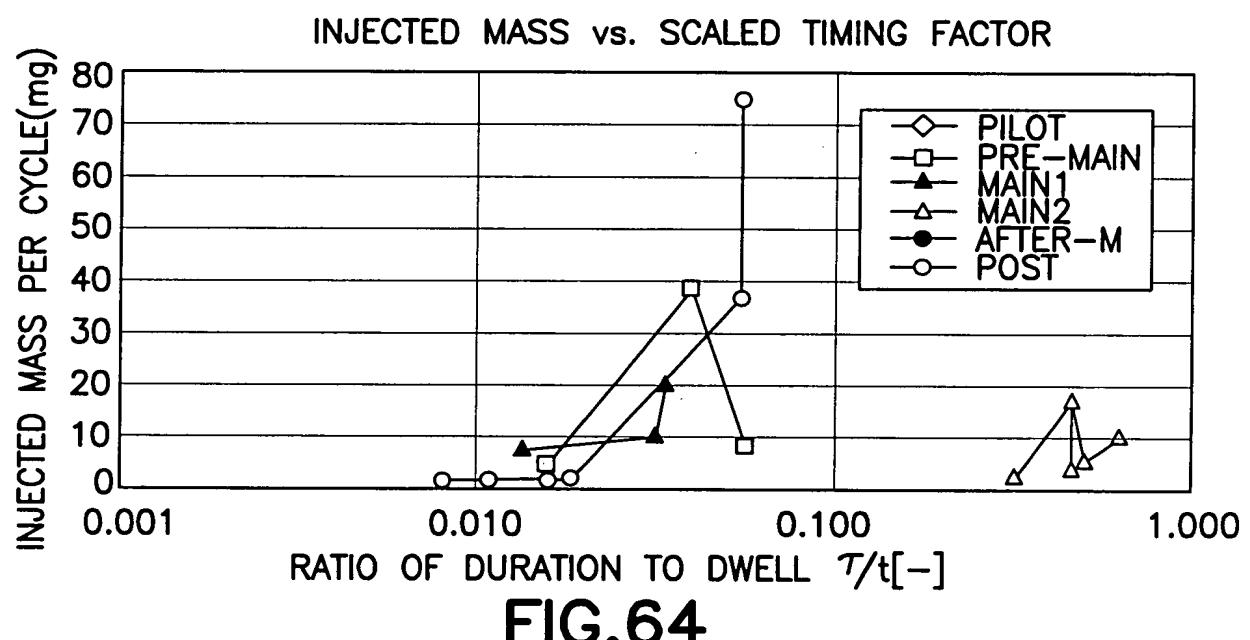


FIG.63



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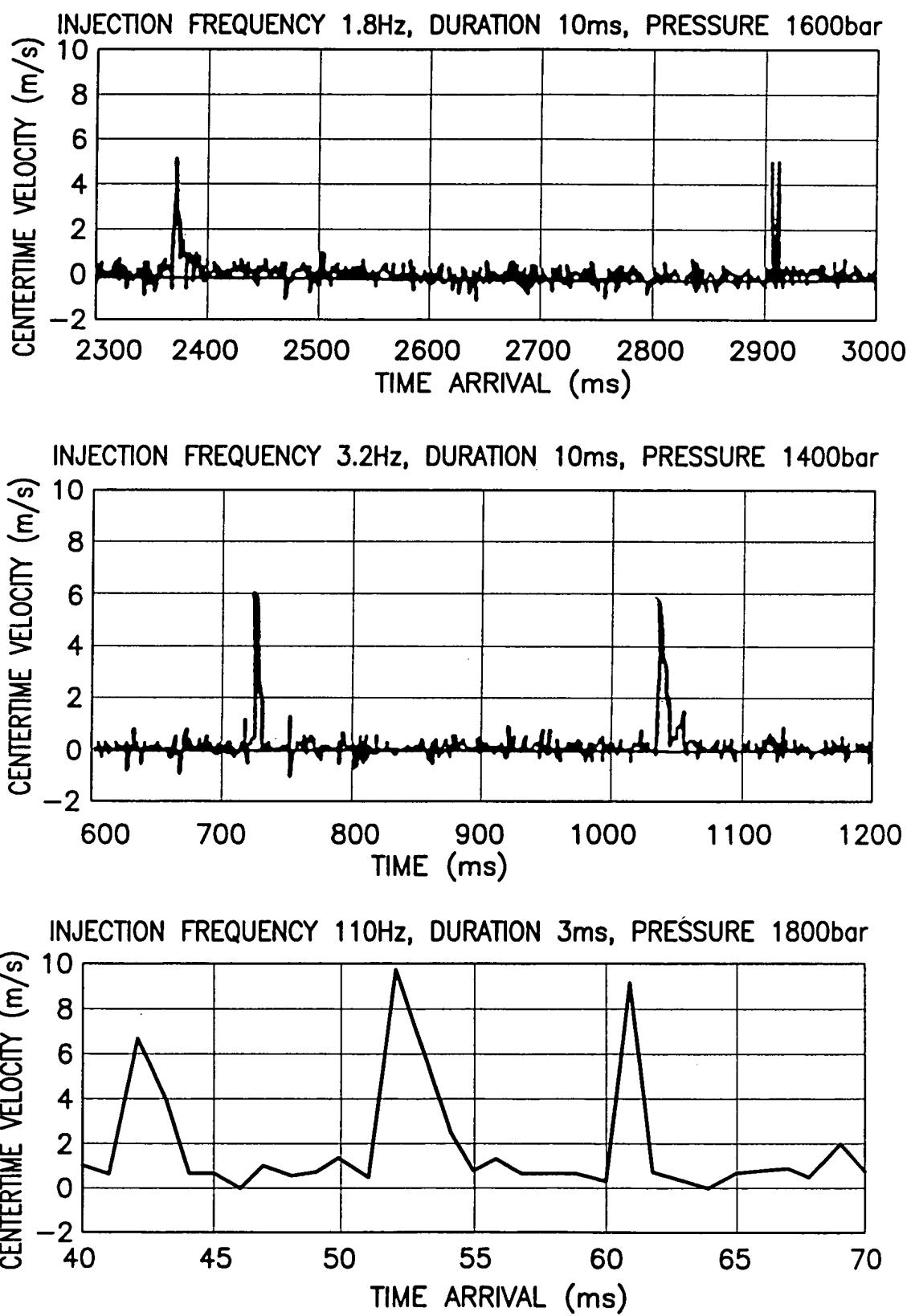


FIG.65

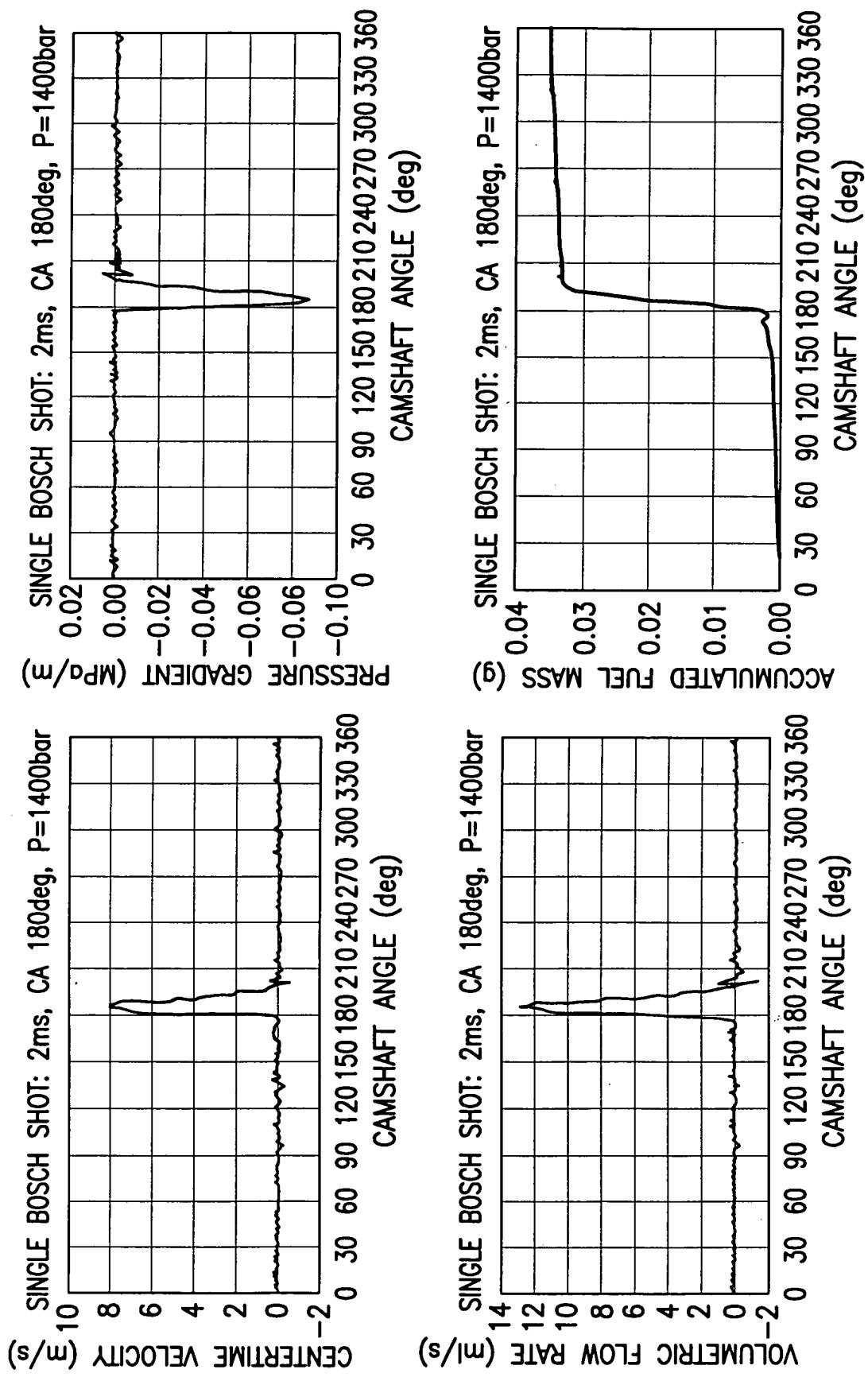


FIG. 66

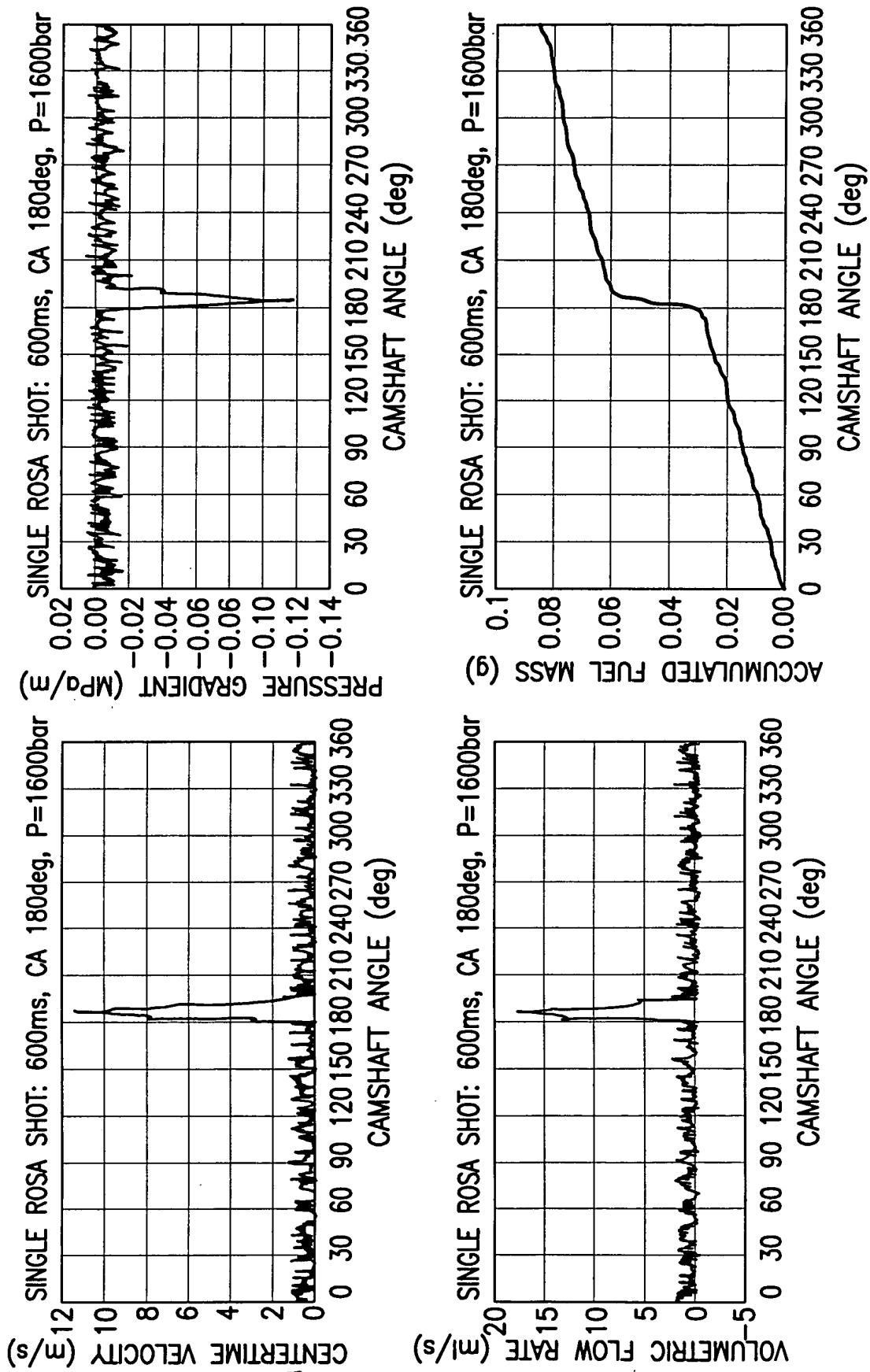
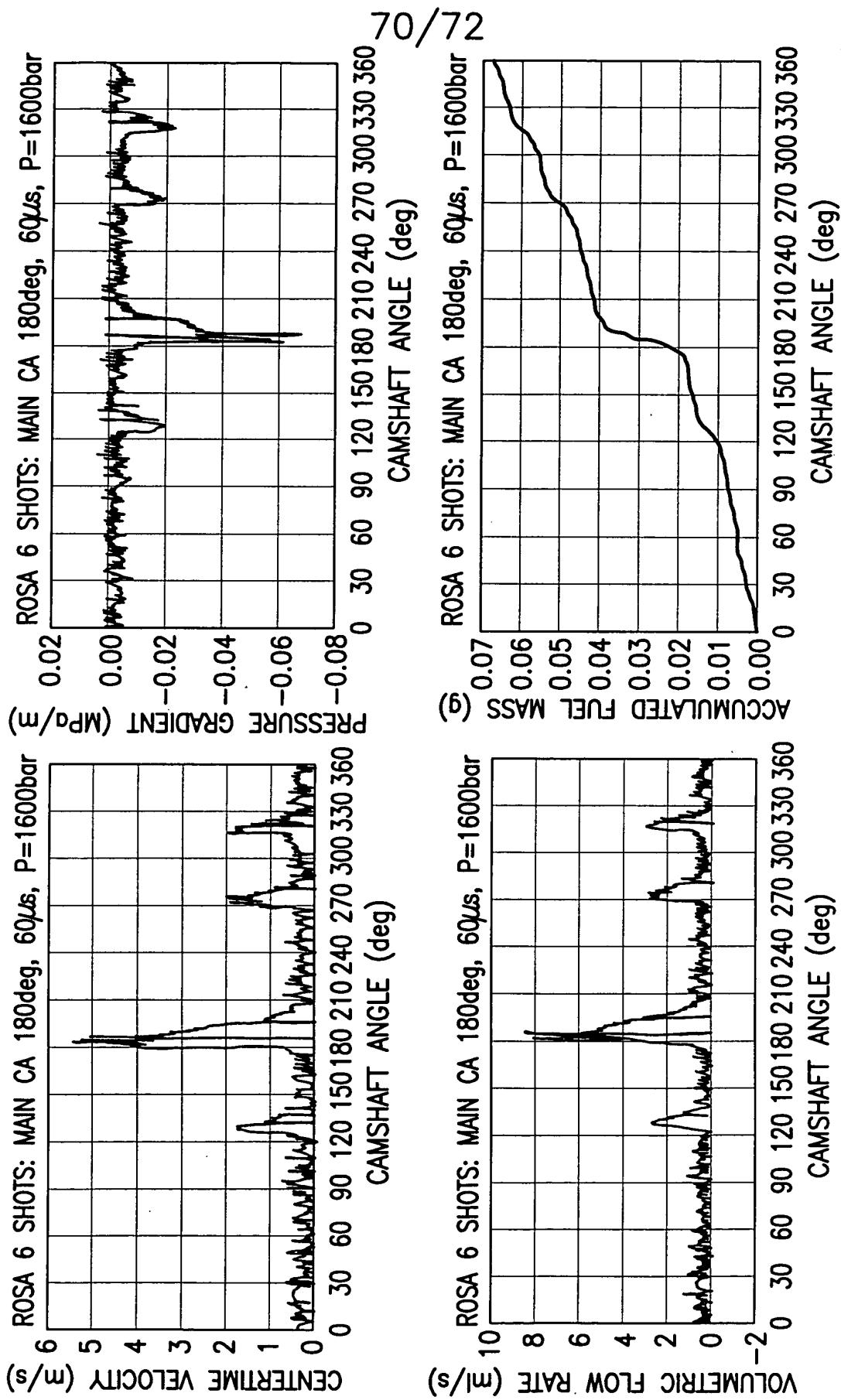
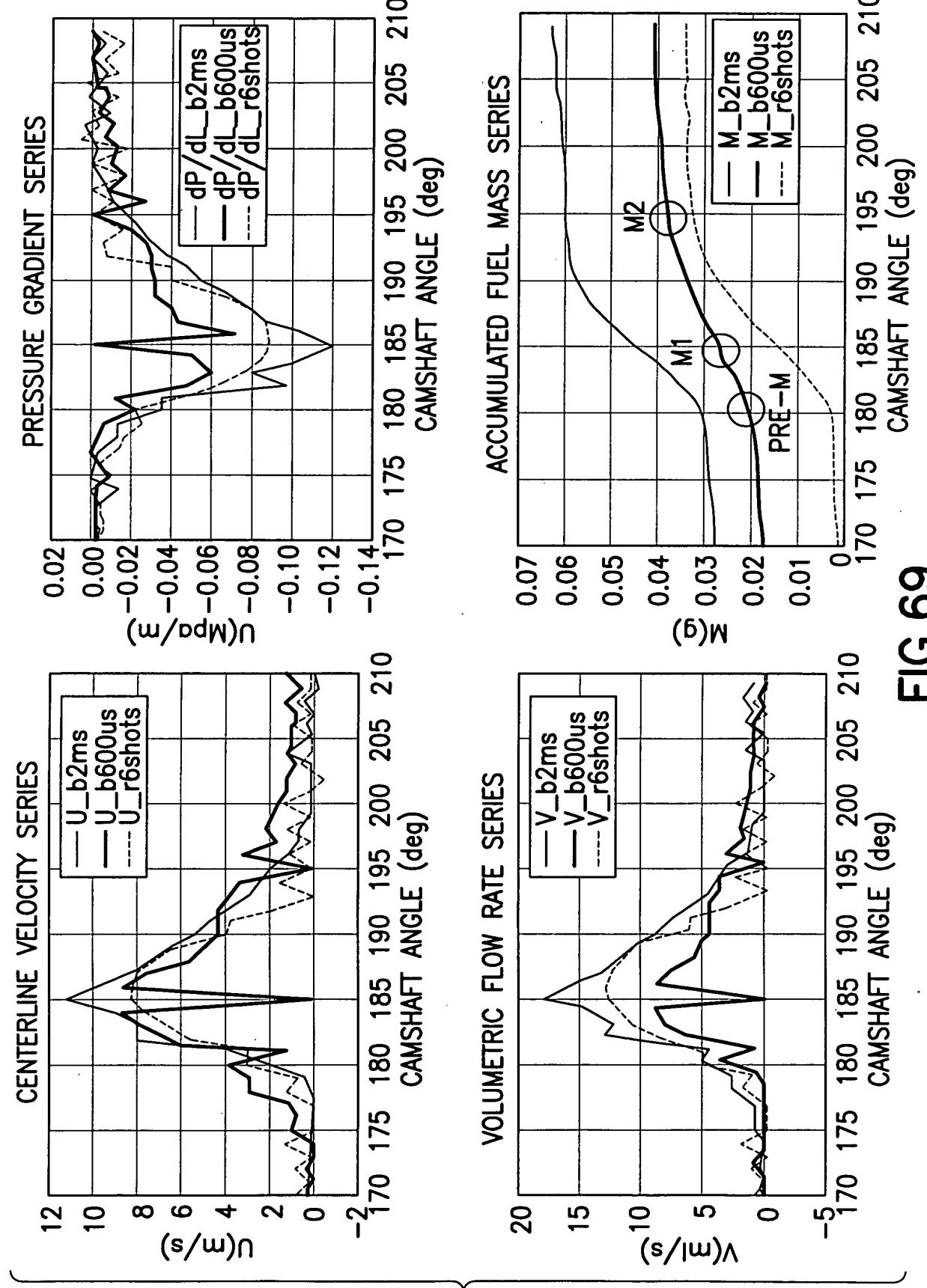


FIG.67

FIG. 68



**FIG. 69**

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	SHOT/PASS	START deg	END deg	DURATION ms	MASSES mg	% OF TOTAL %
1	DELIVER 1	0	125	34.72	10.74	14.8
2	PILOT	125	133	2.22	4.18	5.8
3	DELIVER 2	133	175	11.67	4.33	6.0
4	PRE-MAIN	175	182	1.94	4.47	6.2
5	MAIN 1	182	186	1.11	7.30	10.1
6	MAIN 2	186	196	2.78	11.65	16.1
7	DELIVER 3	196	269	20.28	10.62	14.7
8	AFTER-M	269	281	3.33	5.81	8.0
9	DELIVER 4	281	315	9.44	5.02	6.9
10	POST	315	327	3.33	4.76	6.6
11	DELIVER 5	327	360	9.17	3.54	4.9
	TOTAL: INJECTED DELIVER				72.42 38.17 34.25	100.0 52.7 47.3

FIG.70